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ABSTRACT

One of twelve water treatment technology units, this student manual on distribution systems provides instructional materials for six competencies. (The twelve units are designed for a continuing education training course for public water supply operators.) The competencies focus on the following areas: types of pipe for distribution systems, types of valves in water systems, meter types, disinfecting lines and storage tanks, clear well storage and elevated storage, and storage tank parts. For each competency, student objectives, resources (information sheets and appendix materials), learning activities, and evaluation activities are provided. The appendices contain information sheets on materials and meters, valves, valve maintenance, disinfecting mains and storage tanks, and recoating storage tanks. Generally, an evaluation form with answer key is provided for each competency. (JH)

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Water Treatment Technology

DISTRIBUTION SYSTEMS

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U S DEPARTMENT OF HEALTH, EDUCATION & WELFARE
NATIONAL INSTITUTE OF EDUCATION

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CE 022 518

DISTRIBUTION SYSTEMS

EVALUATOR'S COPY

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EVALUATOR'S INSTRUCTIONS

Name _____

Address _____

_____

Phone _____

This is your EVALUATOR'S COPY of the DISTRIBUTION SYSTEMS unit. It contains all of the materials received by the operators who will be working on the unit. It also contains *answer keys* and *directions* for the evaluation of each competency. For each Competency Sheet, there is a COMPETENCY, a list of RESOURCES, LEARNING ACTIVITIES, and EVALUATION ACTIVITIES.

Your student operators will call you when they are ready to be evaluated. An operator may complete the evaluations in *any* order. S/he may choose to complete one at a time, or several at one time. *It is up to you and each operator to set convenient schedules for the evaluations.* It is important that the operators learn the skills listed in each competency. It is <u>your</u> job to be sure the operators can perform the competencies.

If an operator does <u>not</u> complete an evaluation correctly, s/he may try again later after practicing the skills. It would be helpful for you to tell the operators just how they should improve their knowledge and skills in order to complete the evaluation successfully. Be sure to call if you have any questions.

This package contains:

- - - - - DISTRIBUTION SYSTEMS unit

- - - - - Evaluation Forms for each competency

You will receive instructions as to where to send the completed evaluation forms. Please be sure that the operator's name and your name are on the forms, as well as the date on which the evaluation was performed.

INSTRUCTIONS FOR THE STUDENT OPERATOR

The DISTRIBUTION SYSTEMS unit contains six competencies. A "competency" is a skill that is necessary for good on-the-job performance. Each competency in this unit is necessary for you to perform on the job according to the West Virginia Department of Health. There is a Competency Sheet to help you understand each competency.

DIRECTIONS FOR COMPLETING THE UNIT:

1. Reach each Competency Sheet carefully. Every Competency Sheet contains:

   COMPETENCY
   Objectives
   RESOURCES
   LEARNING ACTIVITIES
   EVALUATION ACTIVITY(IES)

2. After reading the whole Competency Sheet, you should understand what will be expected of you.

3. Do the LEARNING ACTIVITIES that you think will help you the most. This may include reading some of the RESOURCES which have been included with the unit.

4. If you need additional help, ask an operator in your plant for assistance, or call your evaluator; he's there to help you.

5. When you are ready to complete the EVALUATION ACTIVITY for one or more competencies--call your evaluator. The two of you will schedule the best time for your evaluation.

   a. If you complete the evaluation correctly, go on to the next competency.

   b. If you do <u>not</u> complete the evaluation correctly, your evaluator will tell you what your mistakes were. You must go back and practice your skills and read the RESOURCES again. Call your evaluator when you are ready to try again. *You must wait at least one week before being re-evaluated on a competency.*

SEE NEXT PAGE

6. When you complete all your evaluations correctly you will receive a Certificate of Accomplishment and 1.2 Continuing Education Units of Credit.

7. If you want to go on to another unit, contact your evaluator for the materials. The procedure will be similar for all units.

AN EXPLANATION OF CONTINUING EDUCATION UNITS

For student operators in the OPERATOR-IN-TRAINING category who will be taking the certification examination for Class I, this course is an opportunity to increase your knowledge and competence in the treatment of water for human consumption. Successful completion of the manuals will also, it is hoped, make passing the certification exam much easier. The Continuing Education Units which you will get by taking this course will not decrease the minimum one year operating experience requirement for a Class I certificate.

For student operators who now hold a Class I certificate, the completion of all twelve manuals in the course will reduce the currently required three years of total operating experience for Class II certification by approximately four months. Thus, if you complete the course, you will need only two years and eight months of total operating experience before you take the Class II exam.

Here is a listing of the Continuing Education Unit (CEU) value of each of the manuals.

Manual	CEU Value
General Plant Operation	1.4
Taste, Odor, and Color	0.6
Chemistry/Bacteriology	2.5
Chlorination	2.5
Fluoridation	0.6
Filtration	1.2
Hydraulics	0.6
Distribution Systems	1.2
Pumps	0.6
Wells	1.0
Cross Connections	0.4
Springs	0.4
Total	13.0

For comparison with other types of training previously available, the CEU conversions below are given.

Public Water Supply Operator's Short Course (given by State Department of Health Personnel)	4 CEUs
One Semester Hour of College Credit	1.5 CEUs
One Year of College Credits (30 semester hours)	45 CEUs

COMPETENCY: Describe three types of pipe that could be used in a water system and the advantages of each.

Objective: Identify and describe various types of pipe used in water systems.

Objective: Identify all types of pipe that are used in your treatment plant's distribution system.

RESOURCES: (a) Waterworks Manual - basic, P71-54, Coordinating Council for Occupational Education, State of Washington, 1972, pp. 85-100. *-Yellow Appendix-*

LEARNING ACTIVITIES:

(a) Read the Resource listed above to find information about the various types of pipe used in water distribution systems.

(b) Have an experienced operator "tour" parts of the distribution system with you. Make note of all the various types and sizes of piping material used. Identify the types of joints used to connect various types of pipe.

(c) Using the Resource as a reference, determine the three types of piping material that would be most appropriate for your distribution system. Keep in mind cost, the terrain, and weather conditions. What size for each type of pipe would be most appropriate? Describe the advantages and disadvantages of each.

EVALUATION ACTIVITY: You will be expected to identify three types of pipe that would be appropriate for your distribution system. You should describe where in the distribution system the pipe should be used, the size you recommend, and the advantages and disadvantages for each of the three types of pipe.

Operator _____

Evaluator _____

Date _____

Complete the information below for the three types of pipe you recommend for your treatment plant's distribution system.

1. Type of pipe _____

   Location in distribution system _____

   _____

   Size recommended _____

   Advantages *Note to Evaluators: Please discuss the operator's recommendations with him/her. It is important that all information is complete for each type of pipe.*

   Disadvantages _____

   _____

   _____

2. Type of pipe _____

   Location in distribution system _____

   _____

   Size recommended _____

   Advantages _____

   _____

   _____

   Disadvantages _____

   _____

   _____

3. Type of pipe _____

Location in distribution system _____

_____

Size recommended _____

Advantages _____

_____

_____

Disadvantages _____

_____

_____

COMPETENCY: Identify and describe all types of valves used within your plant and distribution system.

Objective: Describe the various purposes for which valves may be used in water systems.

Objective: Identify the various types of valves that are commonly used in water systems.

Objective: Identify the types of valves used within your treatment plant and distribution system and describe the purpose of each.

Objective: Describe maintenance procedures for the types of valves used within your water system.

RESOURCES:

(a) Waterworks Manual-basic, P71-54, Coordinating Council for Occupation Education, State of Washington, 1972, pp. 101-110. *-Pink Appendix-*

(b) Maintenance and Operation of Water Plants and Systems, Department of the Air Force, Air Force Manual No. 85-13, June 1968, pp. 461-481. *-Green Appendix-*

LEARNING ACTIVITIES:

(a) Read the Resources listed above to find information about valves commonly used in water plants and distribution systems.

(b) Have an experienced operator "tour" the plant and parts of the distribution system with you. Identify the location af all gate valves. Iden- the location and function(s) for the various types of valves. How often are maintenance checks performed on the valves? What type of maintenance records are kept? If none are kept, what specific information should be recorded from valve maintenance checks?

EVALUATION ACTIVITIES:

(a) Complete Evaluation Form #45. It contains questions about the purpose of various types of valves. It also contains questions about proper maintenance procedures for valves. You may use references.

(b) Take your evaluator on a "tour" of your treatment plant and distribution system. Identify the various types of valves used. Describe their purpose. Briefly describe maintenance procedures.

(Distribution System #45)
Evaluation Form
EVALUATOR'S COPY
Part I

Operator _____

Evaluator _____

Date _____

Directions: Write the word "True" or "False" in the space provided next to each item. If you answer "False" write the correct answer on the lines under the question.

1. *True* A butterfly valve may often be substituted for on/off service instead of a gate valve.

2. *False* Ball valves should not be used for isolation.

Ball valves are particularly adapted for isolation and throttling.

3. *True* One way to check the operation of a valve is to close it completely, then open it.

4. *False* Valves must be removed from service while being repacked.

Gate valves can be repacked without removing them from service.

5. False — It is important that valve packing be very dry for proper operation.

Dry packing causes operation to be difficult. Packing should be moistened and lubricated with a half-and-half mixture of kerosene and lubricating oil.

6. True — The location of all valves should be recorded in writing.

7. False — In rising stem valves, bent stems will prevent the valve from being closed.

Bent stems allow operation when valve is open or closed but cause binding in the middle portion of travel.

8. True — A backflow preventer should have no discharge from the relief valve opening when water is flowing in the normal direction.

COMPETENCY: Describe the types of main line meters and customer meters used by your treatment plant. If no meters are presently used, describe those which you think would be most appropriate.

Objective: Describe the purpose of main line meters and customer meters.

Objective: Demonstrate the ability to accurately read each meter operated by your treatment plant.

Objective: Describe basic maintenance procedures for meters operated by your treatment plant.

Objective: Identify the types of meters that could be most appropriately used by your treatment plant.

RESOURCES:

(a) Waterworks Manual - basic, P71-54, Coordinating Council for Occupational Education, State of Washington, 1972, pp. 192-196. *-Blue Appendix-*

(b) "Types of Meters" Resource Sheet.

(c) Manufacturer's manual for all meters used by your treatment plant.

LEARNING ACTIVITIES:

(a) Read the Resources listed above to find information about water meters.

(b) Have an experienced operator help you identify the various types of meters presently being used by your treatment plant. Practice reading each meter. What specific information does it give? If your treatment plant does not presently use meters, use the resources available to you to identify the types of meters that would be most appropriate for your treatment plant.

(c) Describe your treatment plant's policy for meter maintenance. What information is recorded on maintenance records? If no records are presently kept, what specific information do you think should be recorded during meter maintenance? Refer to the manufacturer's manual for specific maintenance instructions.

EVALUATION ACTIVITY: You will be expected to describe the type of main line meters and customer meters used by your treatment plant. Your description should include: the name of the type of each meter; the primary function of each meter; how each meter is read; and the maintenance procedures and maintenance records for each meter.

"TYPES OF METERS"*

All meters have a primary element and a secondary element. The primary element is in contact with and is actuated by the water, while the secondary element translates the action of the water flow on the primary element into terms of water quantity or rate of flow. The type of primary element determines meter type.

a. *Primary Elements.* Primary elements generally used in waterworks are of the head-area, velocity-head, velocity, and volume classes. Types in each class are given below.

(1) *Head-Area.* Head-area types include weirs and flumes, used in open channels, and orifices and nozzles with free discharge to atmosphere.

(2) *Velocity-Head.* Velocity-head types include the Venturi, flow nozzle, orifice, and Pitot tube types used in pipes carrying flow under pressure.

(3) *Velocity.* Velocity types include propeller and turbine meters, used principally in larger size closed pipes. Portable propeller meters are also used to determine velocity of flow in open streams and rivers.

(4) *Volume.* The volume type principally used is the nutating or wobbling disk meter. Determination of quantity by water-level changes as water is discharged into or drawn from a tank of known size is also volume metering.

b. *Secondary Elements.* Secondary elements are actuated by movement or pressure change of the primary element through either mechanical linkage or hydraulic, pneumatic, or electrical impulse. They are classified below in accordance with functions performed. Any combination of the functions may be provided in a single secondary device.

(1) *Indicating.* Indicating devices show only the momentary rate of flow.

(2) *Recording.* Recording devices show continuous rate of flow on a clock-driven chart.

(3) *Totalizing or Integrating.* Totalizing or integrating devices show total volume which has passed through the meter, as in a disk type house service meter.

(4) *Controlling.* Controlling meters control the operation of other waterworks equipment, such as valves and chemical feeders.

*Source: Maintenance and Operation of Water Plants and Systems, Department of the Air Force, Air Force Manual No. 85-13, June 1968, pp. 77-85.

Weirs

Weirs are used to measure flow in channels and streams. A weir consists of a bulkhead or dam across the channel or stream, and a sharp level crest or specially shaped notch mounted on the crest. Volume of flow over the weir varies with the length of the crest or shape and size of the notch, and with the elevation of the water surface above the crest or bottom of the notch. Since both head and cross-sectional area of flow over the weir vary with the flow, it is a head-area meter. Weirs are easily built and give fairly accurate measurement if properly installed. Methods of construction and procedures for using weirs to measure head and compute discharge are described in all standard texts and handbooks on hydraulics.

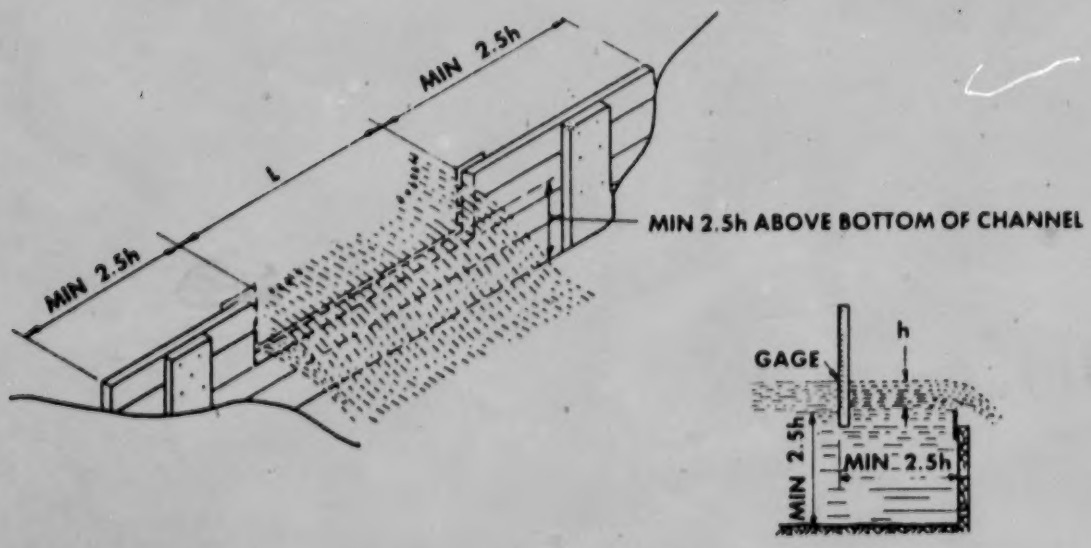
a. *Types.* The more common types of weirs are the rectangular and V-notch weirs described below. If a weir installation requires too great loss of head, a Parshall flume may be used.

(1) *Rectangular Weir:*

(a) Rectangular weirs are suitable for flows over 150 to 200 gpm. The crest should be a sharply beveled metal plate. Figure 1 shows minimum setting of top of crest above the channel, setting of sides of weir and location of gage, in terms of maximum head (h), which should be at least 2.5 inches. Accuracy is greatly reduced if these dimensions are less than indicated, and if length (L) is less than three times h.

Figure 1

Rectangular Sharp-Crested Weir with Complete End Contractions.



(b) The Francis formula for discharge of a rectangular weir, unsuppressed (no end contraction), and omitting the correction for the velocity of approach is: $Q = 3.33Lh^{3/2}$

Where:

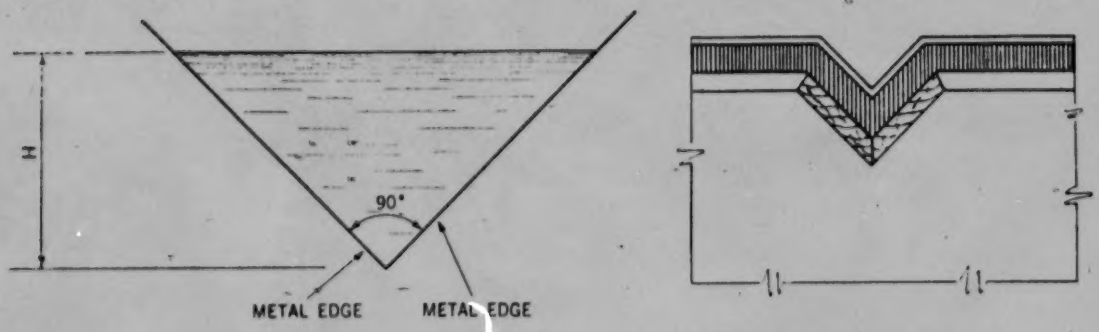
Q = discharge in cfs.
L = length in feet.
h = head in feet.

However, it may be used where the weir extends the full width of the channel (suppressed weir) or where L is greater than 10h. Correction for the approach velocity is based on the following formula: $Q = 3.33h^{3/2}(L-.2h)$.

(2) *90° V-Notch Weirs.* The 90° V-notch weir (Figure 2) is preferred for flow less than 1,000 gpm and is particularly suitable for very low flows.

Figure 2

90° V-Notch Weir.



b. *Operating Guides:*

(1) Keep beveled crest of all weirs sharp and clean.

(2) Keep approach channel free of debris and sediment.

(3) Check and adjust gage frequently to make certain the zero setting marks the water surface when it is at the level of the weir but at zero flow. To make this zero setting, shut off flow of water to weir, and adjust the gage to zero setting when water is at the weir crest level. If flow cannot be shut off, use the following methods:

(a) For hook gages, hold carpenter's level with one end resting on crest and other on tip of hook. Adjust gage at zero setting until level.

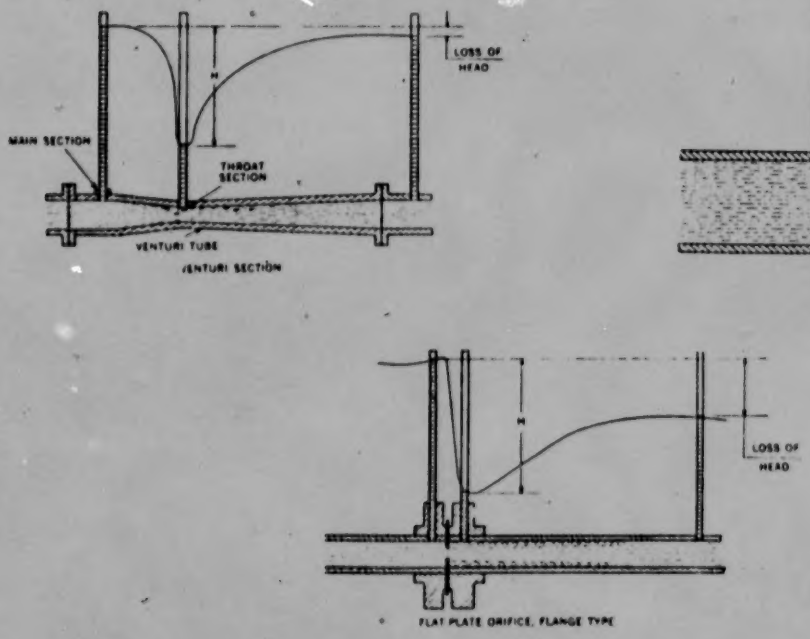
(b) For float gages in a stilling well, mark the crest elevation permanently on the stilling-well wall. Then, to check the zero gauge setting, close off stilling-box connection to flume and bail out water until it is at marked level. If sheaves and counterweights are attached to float, more accurate check can be made by observing the zero gauge reading on both a rising and falling water level.

Venturis, Flow Nozzles, and Orifices

Venturi, flow-nozzle, and orifice meters consist of a restricted area in a pipe, and taps upstream from the restriction and at the restriction to determine the pressure at each point. As water flows through a restriction in a pipe, velocity increases in indirect proportion to the relative decrease in cross-sectional area. The energy used in speeding up the flow causes a corresponding drop in pressure at the point of restriction. Thus the differential pressure between the two taps is a measure of increase in velocity head. This increases as rate of flow increases. Changes in pressure head through these devices are shown in Figure 3. Note that a drop in pressure is produced at the throat section of the venturi and immediately following the flow nozzle or thin-plate orifice, and is partially regained several pipe diameters below the restriction. A standard venturi has a

Figure 3

Changes in Pressures and Permanent Loss of Head in Venturi, Flow Nozzle, and Orifice.



low permanent loss of head because of its streamlined construction. In a thin-plate orifice, the permanent loss is much greater (Figure 4). Loss through a flow nozzle and short-tube venturi lies between these two. Figure 5 shows the permanent loss of head in these devices for various pipe diameter to orifice or throat diameter ratios (D/d), expressed as percent of the differential pressure.

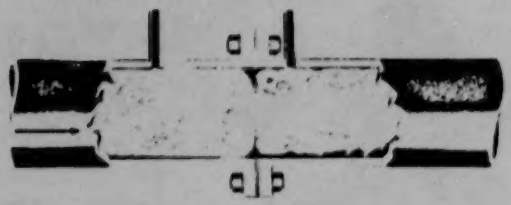
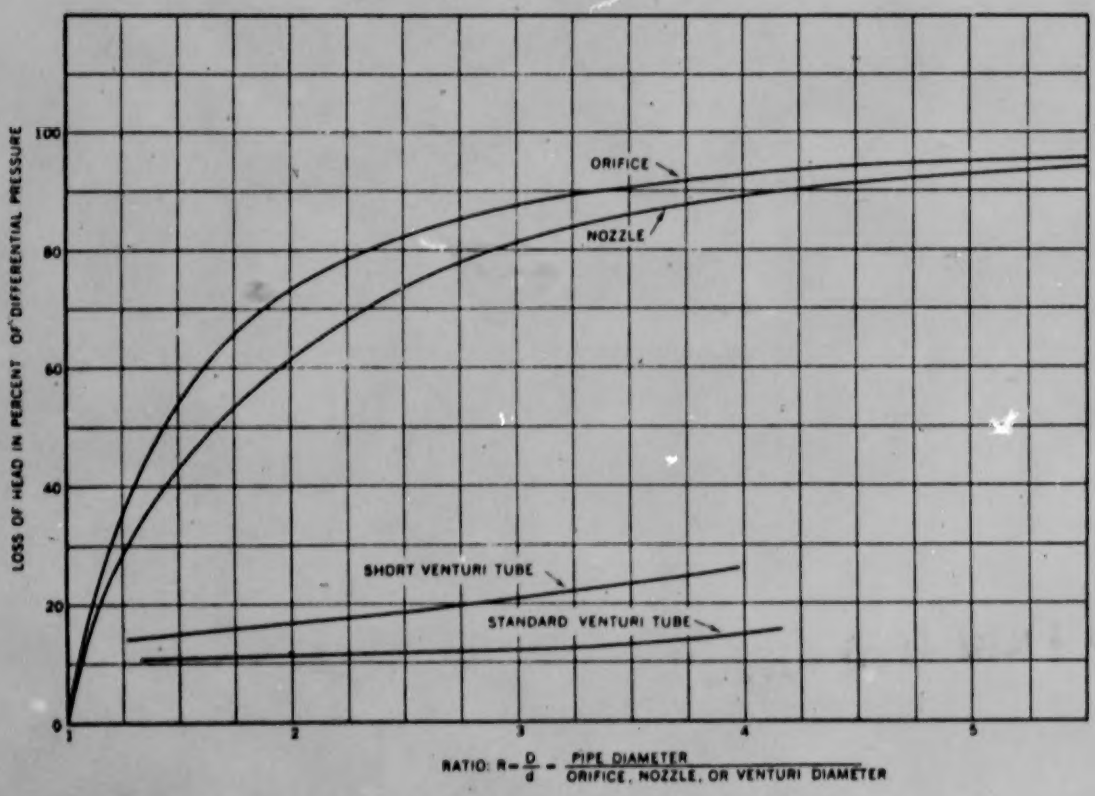


Figure 4

Flow through Orifice Plate, Showing Turbulence Which Causes Loss of Head.

Figure 5

Permanent Loss of Head Expressed as Percent of Differential Pressure.



This loss of head is the major factor in determining which device to install. Although venturi tubes are much more expensive than orifices, the additional cost of a tube is often offset because an orifice requires so much more power to pump against the increased head. In some cases, an orifice can substantially reduce supply below fire-flow requirements if the ratio D/d is greater than 1.67; this factor must be considered carefully before installing orifices in supply lines. Orifices installed at permanent installations should be studied to determine the economic feasibility of replacing with venturi tubes.

a. *Computation of Differential Pressure and Loss of Head.* Rate of flow through venturis, flow nozzles, and orifices can be found from the formula:

$$Qm = \frac{6.3\ CD^2\sqrt{h}}{\sqrt{R^4-1}}$$

or:

$$h = \left(\frac{Qm\sqrt{R^4-1}}{6.3\ CD^2}\right)^2$$

Where:

Qm = gallons per minute
D = diameter of pipe in inches
d = diameter of orifice, flow nozzle, or venturi throat in inches
R = ratio of pipe diameter to orifice or throat diameter, $\frac{D}{d}$
C = coefficient; an average coefficient for orifices is 0.61; for venturi tubes and flow nozzles it is 0.977
h = head (differential pressure) in inches of water; this is the <u>drop</u> in pressure.

The value of $\sqrt{R^4-1}$ can be determined from Figure 6, and the above formula can be readily applied. The <u>percent</u> permanent loss of head can be taken from Figure 5.

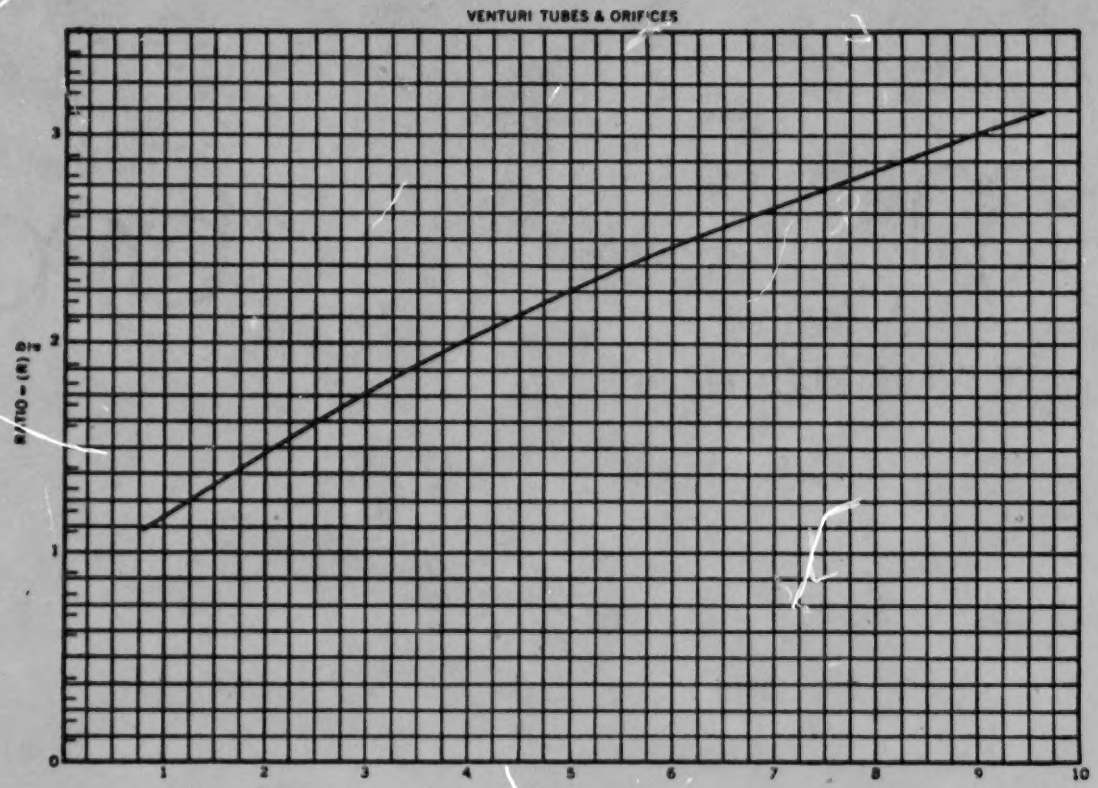
Note: Pressure differentials produced by commercial orifices of the face-tap type (downstream tap adjacent to orifice plate) vary from the values obtained by the above formula. Use the manufacturer's calibration curve for such orifices.

(1) *Example 1.* If size of pipe (D) is 6 inches, size of orifice (d) 3 inches, and differential pressure (h) 9 inches, find the rate of flow.

$$R = \frac{D}{d} = \frac{6}{3} = 2$$

C = 0.61

Figure 6



Value of $\sqrt{R^4-1}$ For Various Diameter Ratios

In this example, $\sqrt{R^4-1} = \sqrt{2^4-1} = \sqrt{16-1} = \sqrt{15} = 3.87$

$$Qm = \frac{6.3 \times 0.61 \times 6^2 \times \sqrt{9}}{3.87} = \frac{6.3 \times 0.61 \times 36 \times 3}{3.87} = 107.25 \text{ gpm.}$$

(2) *Example 2.* With the same conditions, but with a maximum rate of flow of 300 gpm, find the permanent loss of head through the orifice.

$$h = \left(\frac{300 \times 3.87}{6.3 \times 0.61 \times 36}\right)^2 = (8.39)^2 = 70.4 \text{ inches differential pressure}$$

From Figure 5, when R = 2, permanent loss of head for an orifice equals 73 percent of the differential pressure. Therefore, permanent loss of head through the orifice = 70.4 x 0.73 = 51.39 inches.

(3) *Example 3.* Find the permanent loss of head in a standard venturi tube under the same conditions.

$$h = \left(\frac{300 \times 3.87}{6.3 \times 0.977 \times 36}\right)^2 = 27.$$

From Figure 5 , permanent loss for a standard venturi is 11 percent when R = 2. Therefore pemanent loss = 27 x 0.11 = 2.97 inches.

b. *Installation and Operation.* Venturi tubes must have at least 5 and preferable 20 pipe diameters of straight pipe preceding them. Figure 7 shows the pressure chambers at the inlet and throat of a standard venturi tube. These must be kept clean.

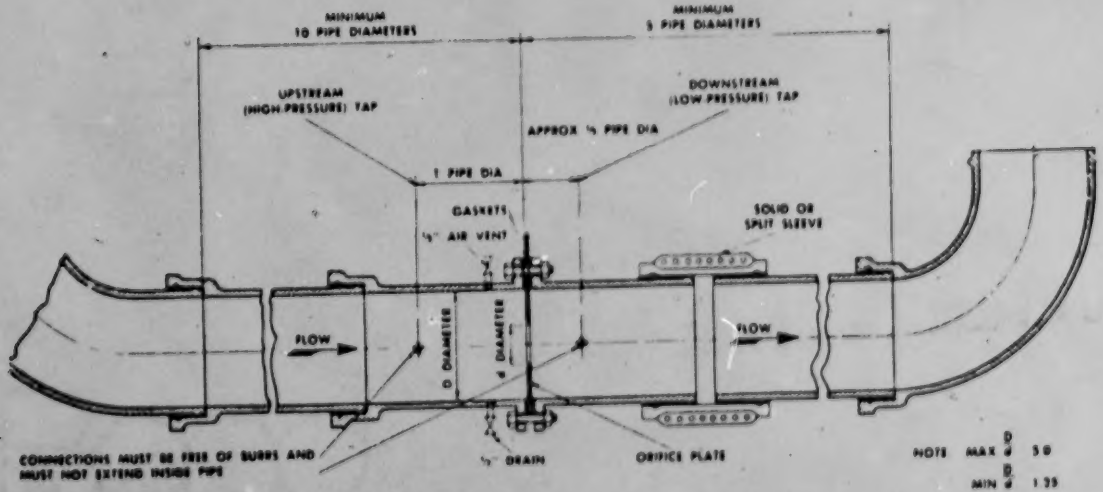
In addition to the standard log venturi, short forms are available, including a type that can be inserted in an existing pipe line. These are less expensive, but have a somewhat higher permanent loss of head (Figure 5). Figure 8 shows how to install a thin-plate orifice between flanges in a pipe line.

Figure 7

Standard Venturi Tube.

Figure 8

Installing a Thin-Plate Orifice Between Standard Flanges.



Pressure taps must be kept clean by periodic flushing. Except for temporary use, thin-plate orifices should be made of monel metal or stainless steel to prevent corrosion which leads to large errors in measurement. In selecting orifice size, the differential produced at high and low flows should be calculated. This is especially necessary for installations to control automatic proportioning chlorinators and hypochlorinators.

c. *Uses.* Although venturi tubes are more expensive metering devices than orifices, they use less head and are more practical in terms of fire flow. In the long run, they may be cheaper than orifices.

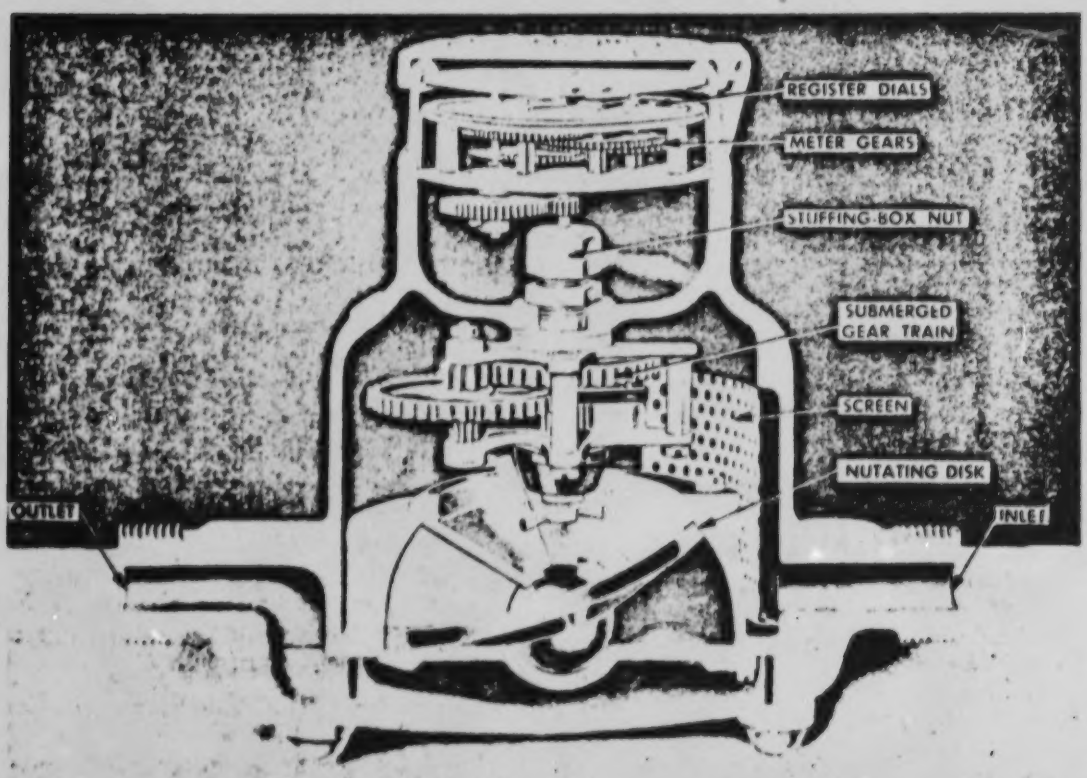
Disk, Turbine, and Propeller Meters

Disk, turbine, and propeller meters normally have an integrally mounted totalizer; they are accurate instruments throughout their rated flow ranges. When used with an orifice or in combination, as in proportional and compound meters, their flow range is extended.

a. *Disk meters.* The nutating-disk type (Figure 9) is mainly used for individual service connections since it is accurate for very low flows. Flows above normal cause rapid wear. It meters by direct displacement.

Figure 9

Nutating-Disk Meter.



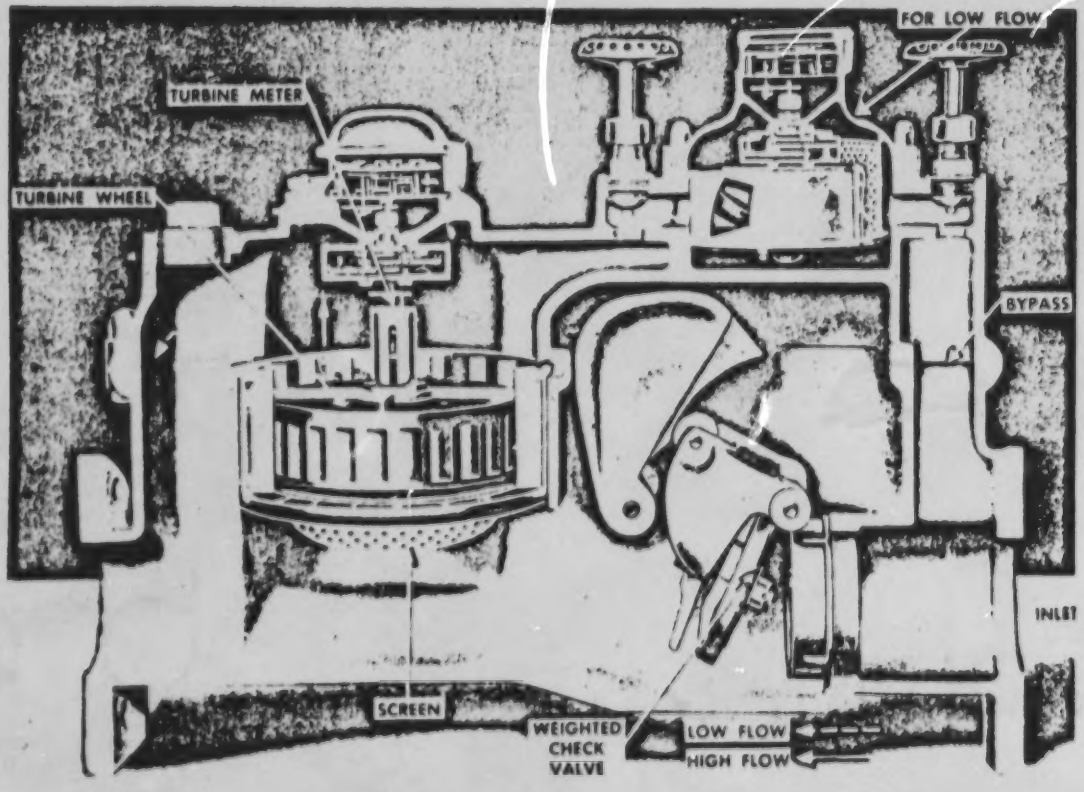
b. *Turbine Meters.* Turbine meters are used on large service lines and in metering supply sources. The turbine wheel revolves with a speed proportional to water velocity. These meters have a high flow capacity with low loss of head. Figure 10 shows a turbine meter as part of a compound meter. The turbine element does not meter low flow accurately.

c. *Propeller Meters.* Propeller meters are used for the same type service as turbine meters and are also velocity meters. Certain designs can be placed in an existing pipe line simply by cutting a large opening in the top and mounting the meter by means of a saddle (Figure 11).

d. *Proportional Meters.* Proportional meters are actuated by the differential pressure produced by an orifice in the line. The disk meter on the bypass between the pressure taps actually measures only a small proportion of the flow, but the totalizer is calibrated to show total flow.

Figure 10

Compound Turbine Meter with Disk
Meter Mounted on Integral Bypass.
Weighted Check Valve Closes During Low Flow



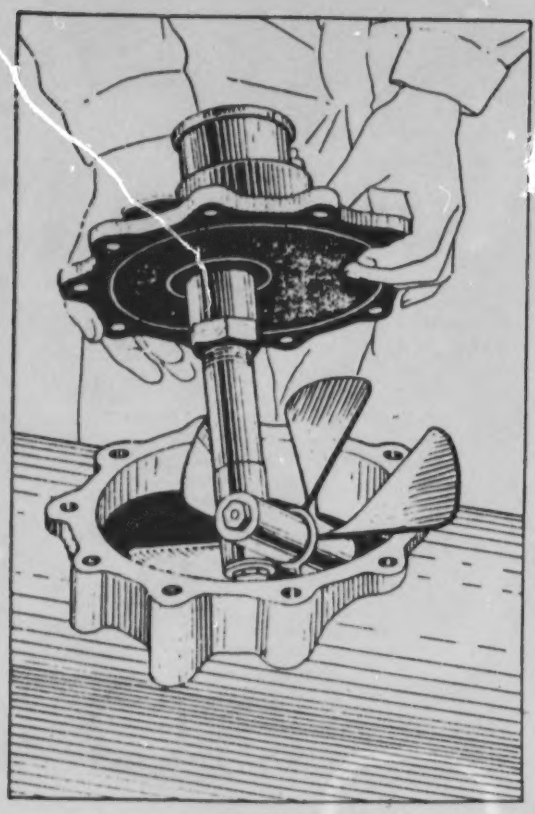


Figure 11

Mounting Propeller Meter
Directly in Pipe Line.

e. *Compound Meters.* Compound meters are designed to meter large and small flows accurately. They may be any combination of meter elements. Figure 10 shows a compound turbine and disk meter integrally mounted. A compound proportional and disk meter with the disk meter mounted on an outside bypass is also available.

f. *Accessories.* Remote indicating, recording, and controlling accessory equipment are available for the above meters. Most municipal waterworks have facilities for testing small service meters. Master meters and portable recording instruments are also available. These instruments can be attached to simple or compound meters to chart flow for 24 hours and determine unusual night flows which may indicate leakage.

Temporary Metering Methods

It is often necessary to determine capacity of pumps which do not have meters. In many cases, certain expedients can be used. During metering by these methods, normal pressure must be maintained on the pump, by throttling if necessary.

a. *Displacement.* If an elevated or ground storage tank is available and can be taken out of service, a simple metering

method is to pump to the storage tank, measuring the rise in elevation at regular time intervals.

b. *Pitot Tube.* A pitot tube is a small tube with a side opening at one end. It is inserted in the pipe through a corporation cock with a packed gland. A side opening faces upstream and transmits both velocity head and pressure head through one of the tubes to one side of a U-shaped manometer. Pressure head is transmitted from the second tap and tube in the downstream side of the tube to the other side of the manometer. Thus the manometer registers only the velocity head. The mean velocity in a discharge line can be determined by traversing the pipe with a pitot tube. For methods, see *Handbook of Hydraulics* by King, or other hydraulics texts.

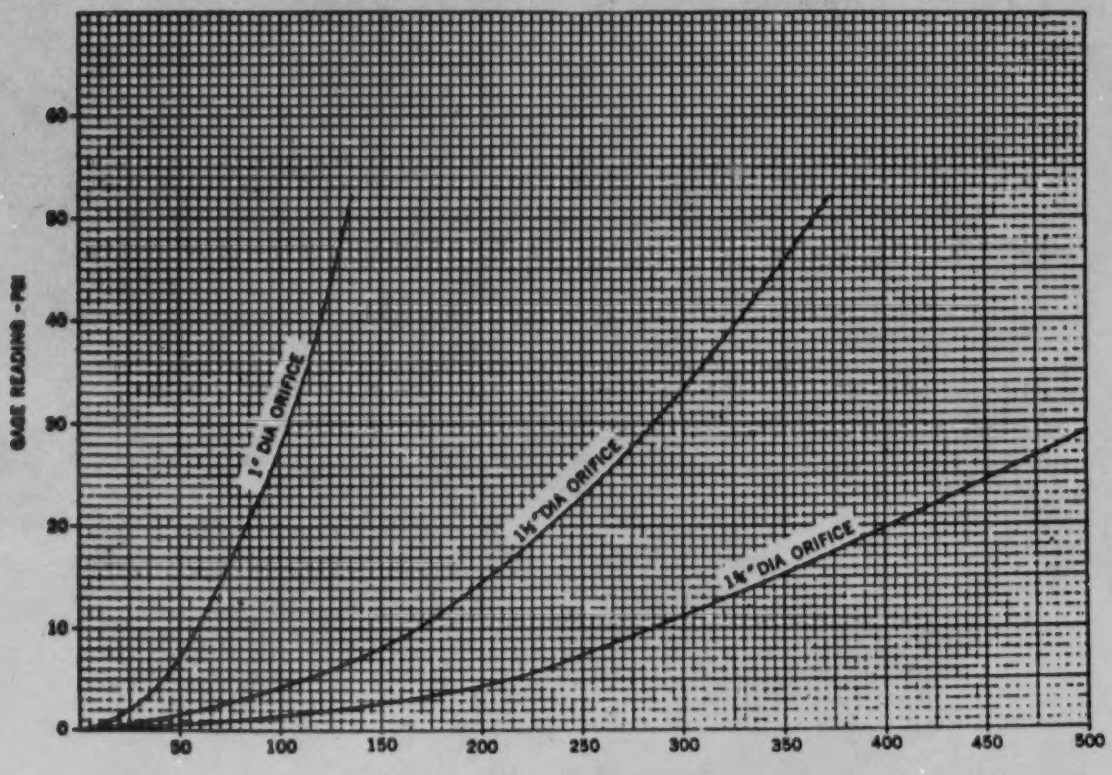
c. *Orifice Discharge.* A simple orifice meter for testing discharge from small pumps, wells, and hydrants can be made with a piece of 2-inch pipe, three 2-inch pipe caps, a 2-inch gate valve, and a pressure gage.

(1) The 2-inch pipe between valve and the cap is 24 inches long. The gage is 8 inches from the cap. The orifices are made by carefully drilling a 1-inch hole in one pipe cap, a 1½-inch hole in the second and a 1 3/4-inch hole in the third. For accurate metering, the holes should be machined to exact size. The downstream sides of the orifices are beveled at a 45° angle, making the perimeter 1/8-inch thick with a sharp 90° edge on the upstream side. This meter can be attached to a fire hydrant, the end of a pipe, or the end of a 2½-inch fire hose.

(2) Rates of flow in gallons per minute through each of the orifices for various gage readings in pounds per square inch are given in Figure 12. For values of R lower than 1.25, theoretical formulas do not apply because of other hydraulic factors that must be considered. The 1 3/4-inch orifice falls into this category; therefore, in preparing the curves in Figure 12, this orifice was calibrated with a test meter. The other orifices were also calibrated. Hence the curves show calibrated instead of calculated values.

Figure 12

Calibration Curves for Orifices
at End of 2-Inch Pipe.



COMPETENCY: Demonstrate the ability to disinfect new and repaired lines and storage tanks.

Objective: Describe procedures for disinfecting new and repaired lines and for disinfecting storage tanks.

Objective: Demonstrate the ability to disinfect a new or repaired line and a storage tank.

RESOURCES:

(a) "Disinfecting Mains and Storage Tanks", *- Buff Appendix-*

(b) "Disinfecting Storage Tanks", Resource Sheet

LEARNING ACTIVITIES:

(a) Read the Resources listed above to find information about disinfecting water lines and storage tanks.

(b) Under the supervision of an experienced operator, disinfect a new or repaired water line. Refer to the resources listed above before you begin. Test the water upon completion to be sure the disinfection was effective.

(c) Under the supervision of an experienced operator, disinfect a water storage tank. Be sure to test the water before returning tank to regular service.

EVALUATION ACTIVITIES:

(a) You will be expected to properly disinfect a new or repaired water line and a storage tank.

(b) Tests taken after disinfection must indicate that the water line and the storage tank have been thoroughly disinfected.

"DISINFECTING STORAGE TANKS"*

Cleaning and Disinfecting

All distribution storage reservoirs and tanks should be entered once each year for cleaning and inspection. They should be hosed down and brushed down at this time and flushed to waste. Before refilling, careful inspection should be made of joints or any other point of potential weakness. Steel structures should be inspected for corrosion and deterioration of paint coatings.

After inspection or repairs have been effected and painting has been completed, a tank should be disinfected before it is placed in service. The tank should be filled slowly to the overflow with potable water, to which sufficient chlorine has been added to provide a concentration of 50 ppm in the full tank. If high-test hypochlorites, with available chlorine of 70%, are used from powder form, an application of 50 ppm of chlorine to 100,000 gallons of water requires 60 pounds of hypochlorite. The disinfectant should be added to the tank in the form of a water mix of the hypochlorite powder using a minimum of water, which is then poured into the tank through a suitable opening. The mix should be added as early as possible in the filling procedure.

After the holding period, the highly chlorinated water in the tank must be drained to a diked holding space until the chlorine residual is 2 mg/l or less before being drained to waste. The tank is then refilled from the regular supply. After refilling, samples of water should be taken from the tank and tested to demonstrate and record the sanitary condition of the tank before it is restored to regular service.

Repairs and Patching

An inspection of a steel tank may indicate areas of considerable corrosion of the plates or deterioration of rivets or leaking welds. Each of these will have to be repaired using methods based on experience of specialized repair men.

If inspection of a concrete structure has indicated that repairs are necessary it is now possible to do a partial repair or patching of concrete walls using the newer plastic water stops and epoxy bonded concrete that have been developed. However, these materials must be approved for potable water use and require specialized handling; their use by inexperienced personnel is not recommended. The original design of a concrete

*Source: Waterworks Manual-basic, P71-54, Coordinating Council for Occupational Education, State of Washington, 1972, p. 198.

reservoir will determine practicable methods of repair. Every precaution must be taken not to disturb the essential structural elements of the reservoir, such as prestressing wires in a prestressed reservoir. The junction between foundation ring wall and reservoir walls in a circular concrete reservoir requires special treatment. A frequent cause of leakage in concrete reservoirs is due to faulty installation of the water stop material during placement of the concrete of the floor slab. Similar faults can occur during construction of the walls. After the repair has been completed, a sprayed-on cement coating such as gunite may be employed as a cover coat.

COMPETENCY: Describe the advantages and disadvantages for your treatment area of clear well storage and elevated storage in the distribution system.

Objective: Describe the purposes of a clear well and clear well storage.

Objective: Describe the purposes of elevated storage in the distribution system.

RESOURCES:

(a) Resource Sheet I: "Clear Wells", adapted from Water Works Operator's Manual, third edition, 1972, Alabama Department of Public Health, Bureau of Enviornmental Health, Montgomery, Alabama, Chapter XVI, P. 15.

(b) Resource Sheet II, "Storage", from Maintenance and Operation of Water Plants and Systems, Air Force Manual No. 85-13, June, 1968, pp 261-263.

LEARNING ACTIVITIES:

(a) Read the Resources listed above to find information about water storage.

(b) Examine the water storage system at your treatment plant. What type of storage system is it? Why was that particular type of storage tank built for your treatment plant?

What are the advantages of clear well storage for your treatment plant? What purposes could it serve in addition to storage (see the Resource Sheet)? What are the disadvantages of clear well storage for your treatment plant?

What are the advantages and disadvantages of elevated storage for your treatment plant?

Refer to the resources you have read about clear well and elevated storage.

(c) In your opinion, what type of storage would be best for your treatment plant: clear well storage or elevated storage in the distribution system? Think through the reasons for your answer.

EVALUATION ACTIVITY: You will be expected to state which type of storage would be best for your water treatment plant (clear well or elevated). You will need to describe the purposes of the type of storage you select. You will also list four advantages and two disadvantages of that type of storage for your treatment plant.

CLEAR WELLS*

1. A clear well provides a place for adequate disinfection after treatment. Chlorine contact time must be at least thirty minutes.

2. A clear well should have a large enough capacity to allow any filter to be backwashed for fifteen minutes plus additional capacity for reserve or to allow simultaneous or sequential backwash.

3. There should be no common walls or connections between a clear well and raw or unfiltered water.

4. All vents and overflows should be screened and adequately protected.

5. A clear well should be located where it will not be subject to flooding.

6. The influent line and the pump suctions of a clear well should be located so there will be good circulation through the whole reservoir.

7. A clear well should be equipped with a water level gauge so that the operator can always tell how much stored water is available.

*Source: Adapted from Water Works Operators Manual, Third Edition, 1972, Alabama Dept. of Public Health, Bureau of Environmental Health, Montgomery, Alabama, Chpater XVI, p. 15.

STORAGE*

General

The normal water demand in a community or installation varies considerably between night and day and for different days of the week. In addition, the fire demand may have to be met at any time. Capacity of supply lines, wells and pumps is often not large enough to meet peak demands, nor would it be economical to provide such capacities. These problems are met by providing storage capacity in the distribution system. During low demand periods water is placed in storage for use during periods when the demand exceeds the capacity of the source, supply lines, treatment plant, or pumps. Storage also enables water to be supplied during emergency conditions resulting from fires, power failure, breakdown of supply pumps, failure of supply mains, flooding, and other conditions that may result from natural causes or accidents. Water may be stored in ground or elevated reservoirs, tanks, or standpipes. Under no conditions of normal use should the amount of stored water be reduced to a point below that necessary for firefighting. Reservoirs or storage tanks at higher elevations than the distribution system, or the portion of it which they serve, maintain the desired pressure in the system. Live storage, where the water is replaced constantly and returned to the system, is preferred to dead storage, because the latter depletes the chlorine in the water and allows tastes and odors to develop.

Ground Storage

Ground storage reservoirs should have waterproof covers to prevent contamination, for open reservoirs are subject to pollution with airborne dust and bacteria, animals and their excreta, leaves and similar debris, and dangerous materials intentionally or accidentally introduced by man. The covers are safeguards against drownings. Algae growths are difficult to control in the presence of sunlight in open reservoirs and may require periodic dosing of the reservoir with chlorine, copper sulfate, or other chemicals. Covered reservoirs or tanks must be vented to allow the passage of air in and out of the reservoir as the water level is changed. The

*Source: Maintenance and Operation of Water Plants and Systems, Air Force Manual No. 85-13, June 1968, pp. 261-263.

vents must be finely screened to prevent entrance of animals and insects, and the screens kept in good repair. Access manhole covers should always be kept in place to prevent accidents and contamination. The ground should slope away from the reservoir in all directions so no surface water can flow towards it. Leaks in the cover or walls that permit the entrance of surface water or shallow ground water are dangerous and must be repaired immediately. In freezing areas, inspect vent screens frequently to keep them clear of ice and frost. Where storage tanks are used only for fire protection, operate fire pumps and recirculate tank contents as frequently as required to prevent or reduce ice formation. The construction of earth banks around storage tanks will help insulate tanks and prevent freezing. Where these measures will not stop freezing, install steam or hot water coils.

Elevated Storage

Elevated storage is provided by means of standpipes or tanks. Standpipes are large-diameter cylinders that rest on the ground. Elevated tanks are supported on columns or legs. The tanks may be of cylindrical, spherical, ellipsoidal, conical, or other shapes. Steel is generally used for tanks, but smaller temporary ones are sometimes made of wood. Water is maintained at the desired level by means of valves and regulators. The function of elevated storage is similar to that of ground storage. The choice between the two depends on the elevation at which water should be stored for the best operation of the distribution system, and the topography of the land. In general, it is desirable to have at least 50 percent of storage as high level storage. However, the problem of freezing is more difficult in the case of elevated tanks.

Freezing. To guard against freezing of water within the riser, cover it with insulating material. In climates where insulation alone may not give adequate protection, install steam coils in the riser and pipe steam to the coils from a nearby boiler plant, or connect a circulating hot-water heater into the riser to take water about 15 to 20 feet above the riser base and return it near the base. In the latter case, adding a small recirculating pump is desirable because it provides a large amount of recirculation with limited heat rise. Inspect vent screens frequently throughout the winter and keep them clear of frost. An ice ring several inches thick may form in elevated tanks, especially if water circulation is slow. In the spring, the ring melts loose from the tank sides and floats to the top of the water. The top of the ice ring is then considerably higher than the water sur-

face. To keep the ring from damaging the top of closed tank or projecting above the top of an open tank, set altitude valves to maintain a freeboard of at least 14 percent of tank depth during the winter.

COMPETENCY: Sketch, label, and describe the basic parts of a storage tank including foundation, valves, vents, and access parts.

Objective: Identify the purpose of all the basic parts of the storage tank(s) at your treatment plant.

Objective: Describe the basic maintenance procedures necessary to keep your storage tank in good working order.

RESOURCES: (a) "Recoating Storage Tanks as Part of Tank Maintenance", *-Gold Appendix-*

LEARNING ACTIVITIES:

(a) Read the Resource listed above to find information about storage tanks and storage tank maintenance.

(b) Have your plant operator show you all the basic parts of the storage tank(s) at your treatment plant. Make note of the foundation, valves, vents, and access parts. Also note the capacity of the storage tank(s).

(c) Practice sketching the storage tank(s) at your treatment plant. You must be able to show all basic parts including the foundation, valves, vents, and access parts. You don't have to be an artist. Just be sure that your sketch indicates the basic parts of the storage tank. Label all the parts you include in your sketch.

(d) Ask the plant operator what type of maintenance has been performed on the storage tank(s) at your treatment plant. Inspect the storage tank(s) at your treatment plant. Are interior and exterior walls clean and painted? Is there much sediment in the bottom? How much corrosion is evident? Make a list of any maintenance which is necessary.

EVALUATION ACTIVITIES:

(a) Complete Evaluation Form #49. It has questions about storage tank maintenance. You must answer every question correctly. You may not use notes.

(b) Sketch, label, and describe the basic parts of a storage tank at your treatment plant. Your sketch must include the tank foundation, valves, vents, and access parts.

(Distribution Systems #49)
Evaluation Form
EVALUATOR'S COPY
Part I

Operator _____

Evaluator _____

Date _____

Directions: In the space provided write the word "True" or "False" next to each item. If you answer "False" write the correct answer on the lines under the question.

1. True — Rust and corrosion can destroy a storage tank if it is not properly protected.

2. False — It is not necessary to empty a water tank to inspect it thoroughly.
The tank should be completely drained and the inside should be washed to remove slime from the walls and sediment from the bottom of the tank before it can be thoroughly inspected.

3. False — The outside of a storage tank should be painted more often than the inside.
Corrosion usually occurs from the inside. The inside should be painted as often as the outside.

4. True — If a storage tank is emptied for inspection, it should be disinfected before it is filled again with water.

5. False — It is not necessary to disinfect a new storage tank before placing it in service.
The tank and fixtures must be disinfected by a solution maintained at 50 mg./l. of free chlorine residual for a minimum of 12 hours. Alternately, spray the interior thoroughly with a solution containing 200 mg./l. of free chlorine residual.

MATERIALS AND METERS*

PIPING MATERIALS

Of the many types of pipe in use, there is no one single type that is best suited for every condition of service. A reasonably thorough knowledge of the advantages, disadvantages, and limitations of each type of pipe is essential to choosing the right one for the job.

Cast Iron Pipe

In the United States today there are more miles of cast iron pipe in water distribution service than any other type of pipe. Cast iron enjoys this distinction because it has been used as a piping material for centuries, and it has a long useful life in underground piping service. It is readily available in sizes from 1 to 48 in. and, on special order, pipes from 48- to 84-in. diameter can be obtained. Most of the 3- to 24-in. pipe used in the Pacific Northwest is furnished in 18-ft. lengths, as this is the manufacturer's standard in the foundries serving the area. In other parts of the country, 12-, 16-, and 20-ft. lengths are common.

Interior corrosion and the formation of tubercules that reduce the carrying capacity of the pipe are major problems in any ferrous piping material. By lining the interior of the pipe with a thin coating of portland cement mortar, an improvement introduced in 1920, interior corrosion of cast iron pipe has been greatly reduced. Most cast iron pipe used today is lined with cement mortar. Friction losses in unlined pipe may be, and frequently are, more than twice as much as in lined pipe.

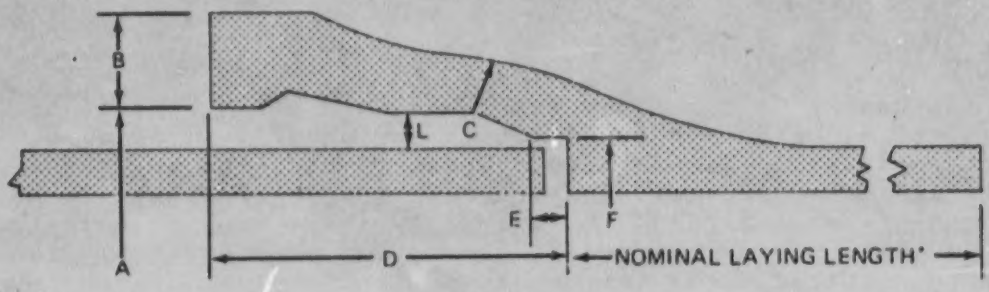
Although many miles of the older type "pit cast" pipe are in service today, virtually all of the pipe 24 in. and smaller, furnished in the last few years, has been centrifugally cast in sand-lined or metal molds. The standard thickness classes for centrifugally cast pipe (American Standards Association specification A 21.1) run consecutively from class 20 to class 30. With normal bedding and backfilling conditions, and for trench depths not exceeding 5 ft., class 22 pipe is usually specified for 3- to 12-in. pipe in systems having less than 150 psi pressure. Heavier wall thicknesses are available for unusual conditions of bedding, impact load, pressure, deep trench conditions, etc.

Cast iron pipe is adaptable to most conditions of service. However, the pipe is subject to excessive corrosion in a highly acid environment where the carbon dioxide content is high. Under these conditions of service, pipe material other than cast iron may be better suited.

*Source: Waterworks Manual-basic, P71-54, Coordinating Council for Occupational Education, State of Washington, 1972, pp. 85-100.

Figure 1

Section through bell-and-spigot pipe joint.



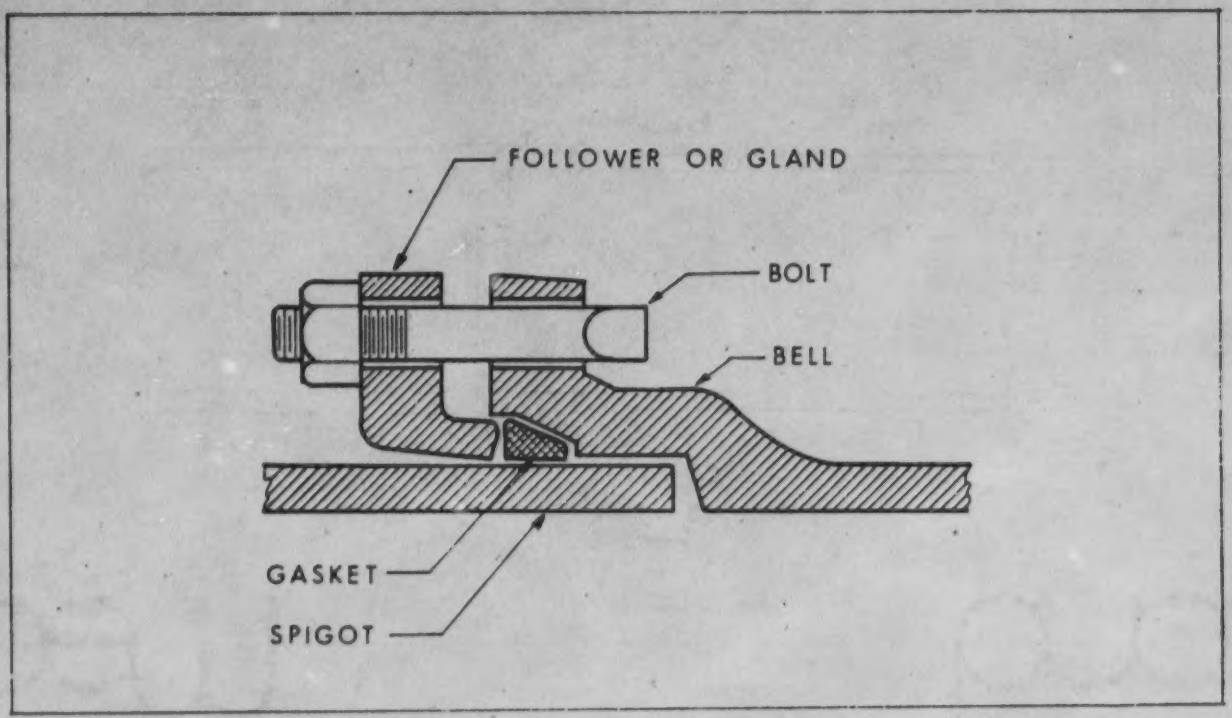
*Bell and spigot pipe has a nominal and actual average laying length of 18 feet.

Until about a quarter century ago, the common type of joint used for connecting cast iron pipe was the bell-and-spigot joint (see Figure 1). To make the joint, a yarning material, braided or twisted hemp, molded or tubular rubber rings, or asbestos rope are caulked into the space between the spigot of the pipe being laid and the bell of the previously laid pipe. Molten lead is then poured into the remaining space and, when cool, the lead is caulked to expand it and thereby develop a watertight seal. In many utilities, it was common to substitute sulphur compounds, which require no caulking, in place of the lead. Slightly moistened portland cement, dry packed into the joint, was another common substitute for lead.

A decade or two ago, the mechanical joint replaced the bell-and-spigot joint as the most popular method of joining cast iron pipe. The mechanical joint is made watertight by wedging a rubber gasket into a tapered groove formed by the bell of the previously laid pipe and the spigot of the pipe being laid. Wedging is accomplished by drawing up bolts between the bell flange and a follower ring or gland (see Figure 2). Although mechanical joint pipe is a little more expensive than bell-and-spigot pipe, the added cost is more than offset by the time saved in making the joint and by reducing significantly the number of joints that must be reworked to produce a completely tight line.

Figure 2

Section through mechanical joint.



Ball joint pipe provides a simple, rugged-type flexible joint for cast iron and ductile iron pipe that is ideally suited for underwater installation where the high cost of equipment and manpower emphasize the importance of speed of assembly and reliability. It may be pulled across streams with a cable as the joints are positively locked against separation. It may also be laid direct from a barge. The pipe and joint are sufficiently strong to support their own weight safely in the water as a beam, when four lengths of pipe are joined together. It therefore may be laid in deep water without the use of divers. The pipe is heavy enough to remain where placed without the necessity for river clamps or other weighting down or anchorage devices (see Figure 3).

In the past few years, a rubber-gasketed, bell-and-spigot slip joint has largely superseded all other types of joints in use in cast iron pipelines. These are provided by various manufacturers under trade names such as Tyton, Bell Tite, Altite, and Fast Tite, etc., all essentially consisting of a rubber or composition gasket fitted and held in the bell end of the joint with the spigot end being shoved into the bell to compress the gasket (see Figure 4).

Figure 3

Section through joint of ball joint pipe.

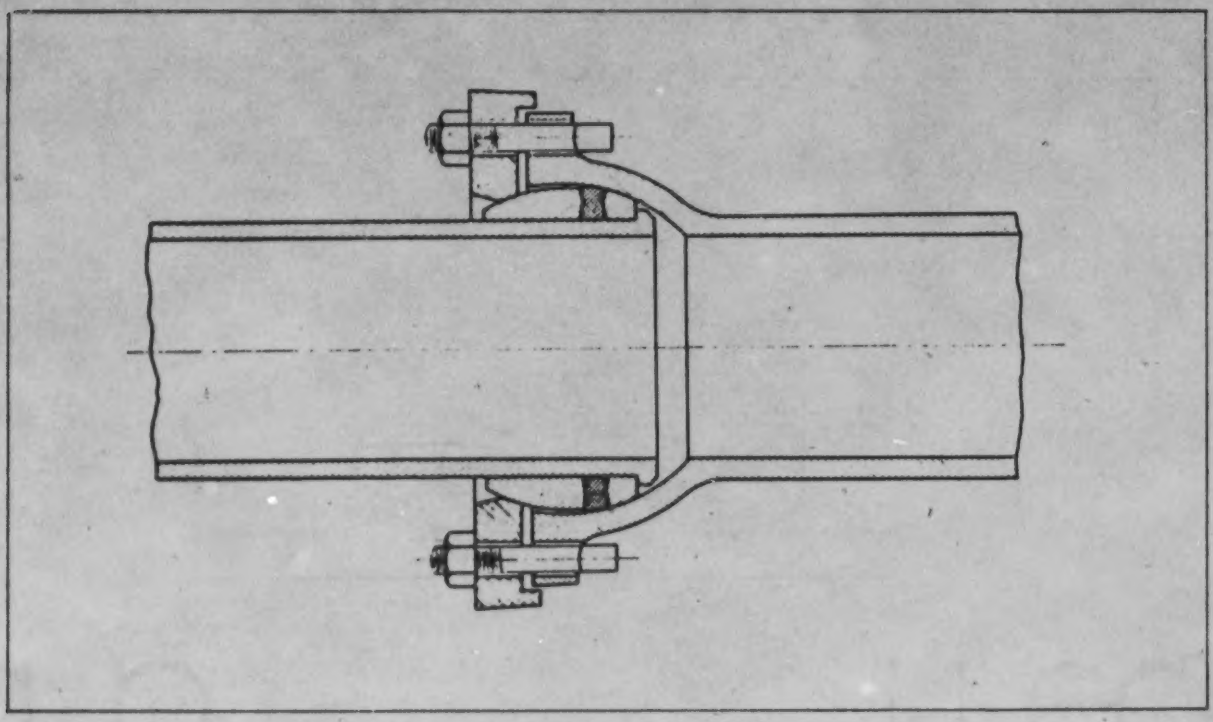
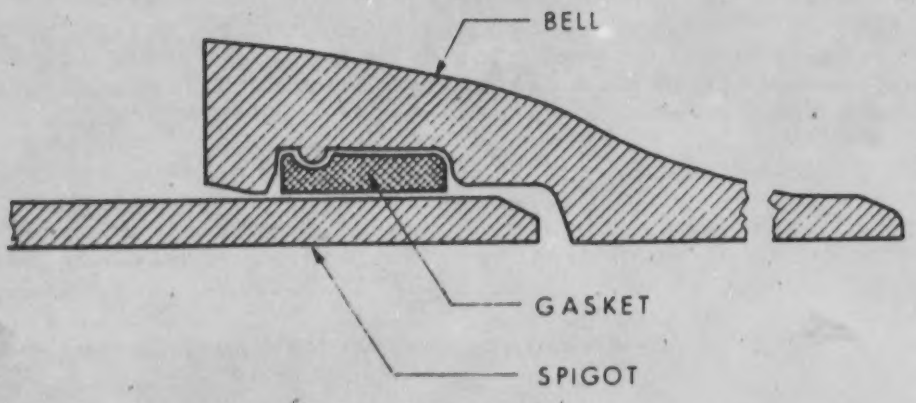


Figure 4

Section through Tyton joint.



Steel Pipe

Steel pipe has played an important part in the distribution of water. "Standard" pipe (ASTM A 120) in the smaller sizes was exclusively for services by many water utilities only a few years back, and much of this pipe is still in service. Most utilities still use limited amounts of standard steel pipe in sizes below 4 inches for short or temporary main extensions.

Standard steel pipe is commonly used in sizes from 1/8 through 4 inches in 21-ft. lengths or random lengths. Seamless steel pipe of the same weight class is available up to 18-in. diameter. For waterworks service, the corrosion protection consists almost exclusively of galvanizing. While galvanizing is usually worth its cost in added life of the pipe, it has limited value against corrosion, and badly tuberculated lines are common in steel pipe.

Standard steel pipe in the larger sizes (4 in. and up) is more expensive than other types of pipe because of its heavy wall thickness. Lined and coated "thin wall" steel pipe compares in cost with other types of pipe, and much of this pipe is used for conveying water--more in transmission than distribution, however. Having comparatively high tensile (stretching or pulling apart) strength, steel pipe with thin walls can withstand normal loads and pressures encountered in waterworks service. To provide the needed corrosion resistance, the pipe is usually lined and coated with coal-tar enamel and covered with an asbestos-felt wrapping material. Dipping the pipe in hot asphalt vats and subsequent wrapping is another type of corrosion protection sometimes used on thin-wall steel pipe. Asphalt-dipped pipe is less expensive than coal-tar enamel, and its corrosion resistance is also less effective. Steel pipe with cement mortar lining and reinforced cement mortar coating, which provides very good corrosion protection, is also available as a standard item.

Thin-wall steel pipe is usually furnished in 40-ft. lengths in sizes ranging from 1 to 60 in. Larger or nonstandard sizes can be furnished on special order. Thicknesses range from 14 gage to 3/8 in. or larger, depending on the requirements. Ten gage (approximately 1/8 in.) is normally the thinnest wall used in waterworks service, except for very small diameter pipe or reinforced, mortar-coated pipe.

Standard steel pipe of smaller sizes is usually joined by threaded couplings with American Standard threads. Thin-wall steel pipe may be furnished with plain ends for Dresser-type couplings, with beveled ends for welding, or with slip joints when using a rubber gasket similar in principle to the cast iron slip joint. Welded joints are rare in waterworks service on pipe less than 24 in. in diameter because the heat destroys the interior protective coating. Other types of joints can be furnished on special order.

Steel pipe is easily installed and joined, is reasonably flexible in service, and can be designed to withstand severe conditions.

Service taps in thin-wall steel pipe are limited to relatively low pressure service areas unless saddles or thread-o-lets are used. For higher pressure service, saddles or service clamps are generally used at service taps. Steel pipe, under most service conditions, will fail by corrosion earlier than cast iron or asbestos-cement and, consequently, steel pipe finds limited use in distribution service. In the larger diameters, however, the first cost of thin-wall steel pipe is much less than cast iron or asbestos-cement, hence the higher percentage of use in water transmission service.

Ductile Iron Pipe

Ductile iron pipe is a relatively new product having been on the market since about 1956. It resembles cast iron in appearance and has many of the characteristics of cast iron, the principal difference being that it is less brittle and more flexible. Accelerated tests indicate that its corrosion resistance is at least equal to that of cast iron.

Ductile iron pipe is particularly suited to bridge crossings, installations supported on piers or piling, under deep fills, unstable bedding conditions, and other conditions where differential movement may cause a failure in the more brittle cast iron pipe.

Ductile iron pipe is available from western foundries in sizes from 4 through 24 in. in nominal 18-ft. lengths, with either mechanical joint or slip joint ends. Larger diameters are available from eastern foundries. The pipe can be threaded or machined and and can be welded by either gas fusion or electric arc. The preferred method of cutting is by a guillotine-type saw or a milling-cutter-type saw. Torch cutting may induce microscopic cracks and is not recommended. Except for special conditions, the in-place costs for ductile iron pipe of 4- to 12-in. diameters will generally be higher than cast iron and, in diameters larger than 12 in., will be slightly lower than cast iron.

Asbestos-Cement Pipe

Asbestos-cement pressure pipe is a highly corrosion-resistant formulation of asbestos fibers, silica, and portland cement. Its extremely smooth interior and its resistance to interior corrosion sustain high water-carrying capacities throughout the life of the pipe under most service conditions. The pipe is easily installed and tapped, and its initial cost in the smaller sizes is relatively low. The principal disadvantage of asbestos-cement pipe, like cast iron, is its limited beam strength or resistance to bending. The pipe must be handled, installed, and bedded more carefully than some other types of pipe. It will tolerate very little differential soil settlement or impact and is easily punctured by rocks or tools. Its nonconductivity, which contributes to its excellent corrosion resistance, is a disadvantage to the extent that electrical thawing is not practical. Asbestos-cement pipe is available in

sizes ranging from 3 to 36 inches. Standard lengths are 13 ft., except for the 3- and 4-in. pipe, which are normally supplied in 6½- or 10-ft. lengths. Ends of the pipe are machined to close tolerances for joining. Joining is accomplished by inserting the ends of the two pipes to be joined into an asbestos-cement collar. Rubber gaskets, compressed between the collar and the pipe, provide the watertight seal and permit the joint to flex. Cast iron fittings are usually used with asbestos-cement pipe.

Concrete Cylinder Pipe

Concrete cylinder pipe is lined and coated with a cement mortar and is particularly suited to transmission pipelines. It has limited application in water distribution systems because it is not as conveniently tapped for new service connections, and the smallest diameter pipe available generally is 10 in. Concrete cylinder pipe, more formally described as "reinforced concrete pressure pipe--modified prestressed," consists of a thin-wall steel cylinder into which a dense cement mortar coating is spun centrifugally to a thickness of ½ in. for pipe up to 16-in. diameter, and 3/4-in. for diameters 18 in. and larger. High-strength steel reinforcing rod, under precisely measured tension, is helically wound around the circumference of the cylinder to provide the strength needed to withstand the design pressure. The rods are welded to the joint rings at each end of the pipe. A thin cement paste is applied to the cylinder ahead of the winding to eliminate voids and to provide an alkaline atmosphere between the two steel segments. Following the wire wrap, an additional cement mortar paste is applied to the rod, thickness is a minimum of 3/4 in. (outside diameter) buy may vary, as does the steel cylinder thickness and rod spacing, to meet the custom design requirements for the service conditions imposed.

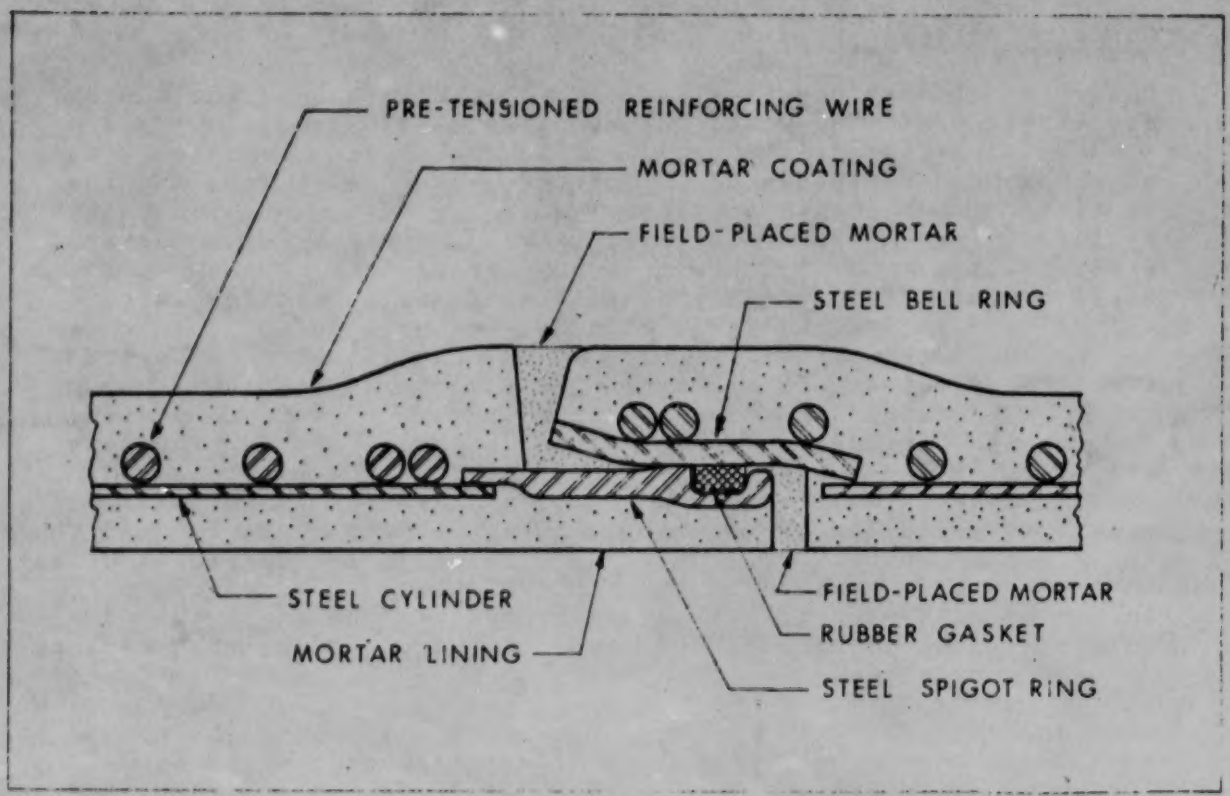
Concrete cylinder pipe is manufactured in the Pacific Northwest in sizes from 10 through 20 in. in 2-in. increments; and from 21 through 72 in. in 3-in. increments. Odd sizes can be furnished on special order. Pipe is normally manufactured in 32- or 40-ft. sections.

Although flanged joints, plain ends for Dresser-type couplings, beveled ends for welding, or other special joint types can be furnished on request, the standard joint is a bell-and-spigot type slip joint employing a rubber gasket for watertight seal (see Figure 5). The bell-and-spigot joint rings are welded to the steel cylinder in the first step of the pipe manufacturing process. To protect the steel from corrosion, the joint spaces, both inside the pipe and outside, are filled with portland cement mortar during the laying of the pipe. In pipe sizes 21 in. and smaller, the interior joint space of the bell is filled with mortar, the spigot of the next pipe is inserted, and excess mortar squeezed out of the joint is smoothed by drawing an inflated swab through the joint. Interior joints on pipe larger than 21 in. are troweled full of mortar after the pipe has been laid and backfilled. Exterior

joints are wrapped with a heavy cloth to completely enclose the joint space, and a thin portland cement grout is poured into an opening in the cloth at the top of the joint until the joint space has been completely filled.

Figure 5

Section through joint of concrete cylinder pipe.



Concrete cylinder pipe has excellent corrosion resistance, is a strong durable pipe, is fairly low in cost, and, because of its smooth mortar lining, has very good hydraulic characteristics. Its principal disadvantages are its heavy weight and the difficulty and cost of tapping.

Concrete cylinder fittings are nearly all "specials" and are custom fabricated. Fittings are frequently fabricated from steel plates of sufficient thickness to withstand the design pressures without pretensioned reinforcement and are concrete mortar coated and lined.

Plastic Pipe

The introduction of plastics as a pipe material in the past few years has raised increasing interest in this material for waterworks use. In an effort to find a service pipeline material more resistant to corrosion than galvanized steel and less costly than copper, many water utilities have experimented with plastic pipe with generally good success and few failures. Although limited data are available as to its comparative service life, the more recent plastics have shown great promise.

There are many types of plastic pipe. The most common in waterworks use are flexible polyethylene tubing, semirigid PVC (polyvinylcholoride), and semirigid ABS (acrylonitrile-butadiene-styrene). Polyethylene joints are normally made by flaring the pipe or using compression-type couplings. PVC and ABS joints may be solvent welded. Extruded and molded couplings are available; the tapered molded couplings are preferred because of the ease of installation. Fittings with iron pipe threads are available, thereby simplifying connections to pipes of different materials. Brass fittings are used frequently at points of external stress, such as connections to corporation stops and meter connections.

Plastic pipe is inexpensive, has good corrosion resistance, is easy to handle and connect, is light in weight, and has good flow characteristics. It has its limitations, however, the major one being the limited information on probable life under actual conditions of service. Such data as are available indicate a reasonable life expectancy. Being nonmetallic, it cannot be thawed by electric resistance methods if frozen nor located underground with electronic pipe locators unless a tracer wire is buried with the pipe.

Wood Stave Pipe

Wood pipe, a very popular piping material a few decades back, is seldom used for new installations in domestic water systems today, although many miles are still in service. The pipe is composed of untreated or creosoted Douglas fir staves held together by metal bands around the outside of the pipe. Wood pipe is furnished in two types. The machine-banded style, in which the pipe is factory-assembled, is furnished in random lengths up to 20 ft. and in diameters from 2 to 20 in. Continuous-stave pipe is available in diameters from 6 to 20 ft. Machine-banded pipe is joined by driving the plain pipe ends into a wood collar. No joint filler or clamps are used. Steel or cast iron fittings are used for sharp bends, branch connections, or other special purposes.

Wood pipe has good flow characteristics, has good resistance to corrosion on the interior, and is easily laid. Although the wood has excellent lasting qualities as long as it remains wet, the life of wood stave pipe is usually shorter than other types due to corrosion of the metal bands holding the pipe together. Wood pipe has its widest application in low-pressure, large-diameter irrigation service.

Copper Tubing

Type-K copper tubing is the most popular service connection material in almost all water utilities. It is readily available in sizes from ½ to 1 in. in 60-ft. or 100-ft. coils; 1¼ to 1½ in. in 60-ft. coils; and 2 in. in 40- to 45-ft. coils or 20-ft. straight lengths. Sizes down to ¼ in. and up to 12 in. are also available but are seldom used in waterworks service. For underground service, type K is used rather than the thinner-walled types L and M. Joints may be either soldered or flared and joined with threaded couplings with the latter being the most common.

SERVICE METERS

The primary function of a meter is to measure and total the amount of water passing through it. There are two basic types: displacement meters and velocity or current meters.

Displacement Meters

The common, small-diameter service meter is of the displacement type. Displacement meters are capable of measuring very small flow rates with relatively high accuracy. Water flowing through the meter is measured by counting the number of times the chamber (a known volume) is filled. In the nutating disc meter, which is a displacement type, the disc is mounted in the chamber with an inclined vertical axis and fixed lower pivot point (see Figures 6 and 7). Water flowing through the meter chamber forces the disc to tilt successively causing the upper end of the inclined axis of the disc to rotate. The disc itself does not rotate about its own axis. The rotating motion is transferred through the gear train to the register dials.

The piston-type displacement meter operates on the same principle, but, in place of the disc, a piston oscillating within a closed cylinder is used to transform the measurement function to a rotating motion (see Figures 8 and 9).

The displacement meter is limited to the comparatively low flow rates associated with normal domestic service. Excessive wear and inaccurate registration occur when displacement meters are operated in excess of the capacities listed in Table 1.

Friction losses in displacement meters are high in comparison to friction losses in current meters.

Current Meters

A velocity meter, or current meter, as it is more commonly called (see Figure 10), registers the volume of water passing through it by measuring the velocity of the flowing water within a known cross-sectional area. Two basic types of velocity meters are in common

Figure 6

Phantom view of split case type nutating disc water meter.

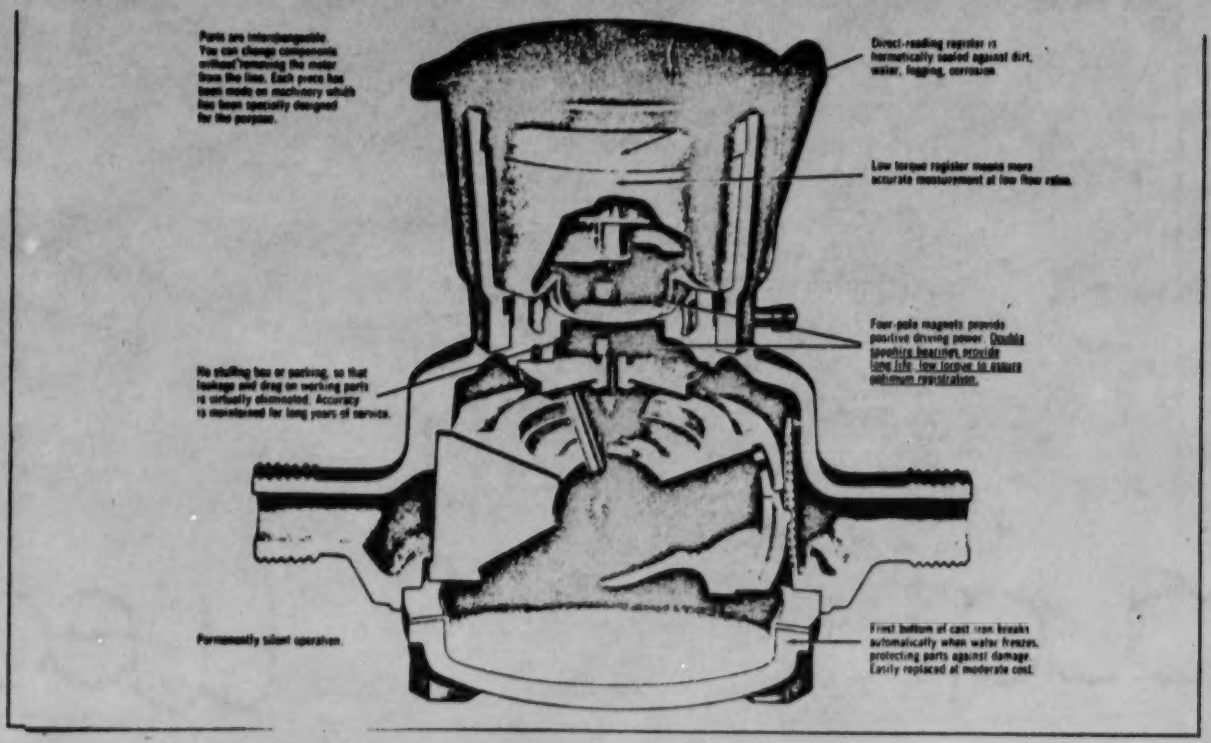

Parts are interchangeable. You can change components without removing the meter from the line. Each piece has been made on machinery which has been specially designed for the purpose.
Direct-reading register is hermetically sealed against dirt, water, fogging, corrosion
Low torque register means more accurate measurement at low flow rates.
Four-pole magnets provide positive driving power. Double sapphire bearings provide long life. Low torque to assure optimum registration.
No stuffing box or packing, so that leakage and drag on working parts is virtually eliminated. Accuracy is maintained for long years of service.
Permanently silent operation.
Frost bottom of cast iron breaks automatically when water freezes, protecting parts against damage. Easily replaced at moderate cost.

Figure 7

Cut away view of frost bottom type oscillating disc water meter.

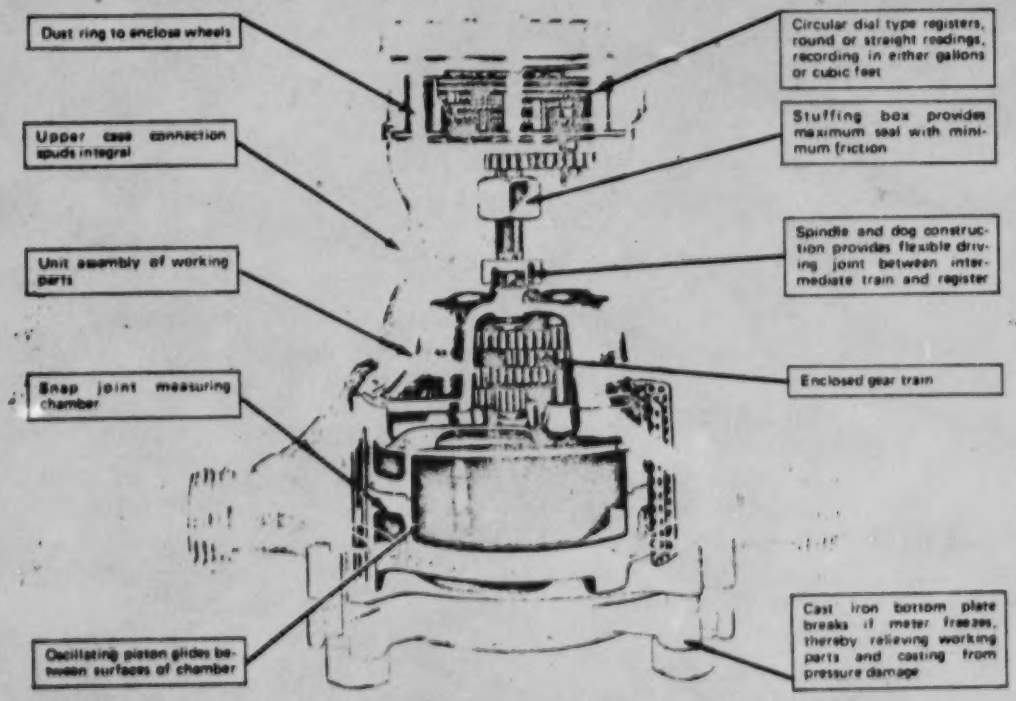

Dust ring to enclose wheels
Upper case connection spuds integral
Unit assembly of working parts
Snap joint measuring chamber
Oscillating piston glides between surfaces of chamber
Circular dial type registers, round or straight readings, recording in either gallons or cubic feet
Stuffing box provides maximum seal with minimum friction
Spindle and dog construction provides flexible driving joint between intermediate train and register
Enclosed gear train
Cast iron bottom plate breaks if meter freezes, thereby relieving working parts and casting from pressure damage

Figure 8

Phantom view of split case oscillating piston water meter.

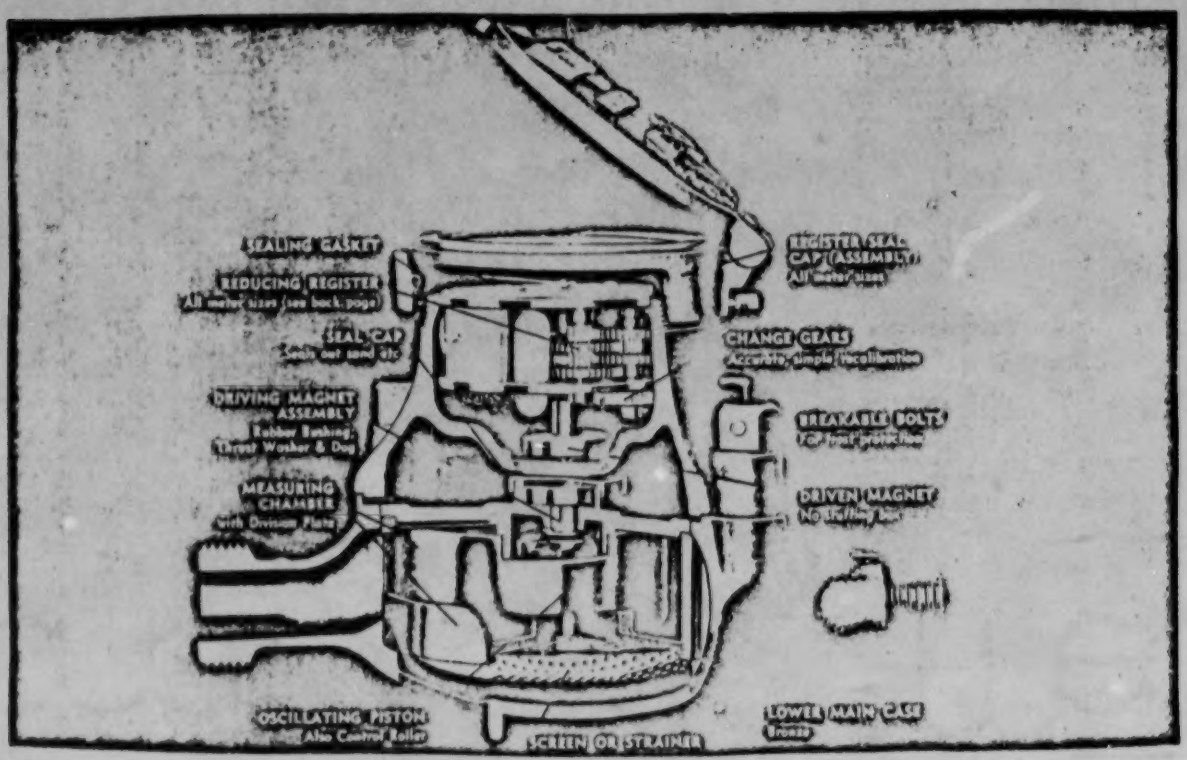


Figure 9

Cross section of frost bottom type nutating piston meter.

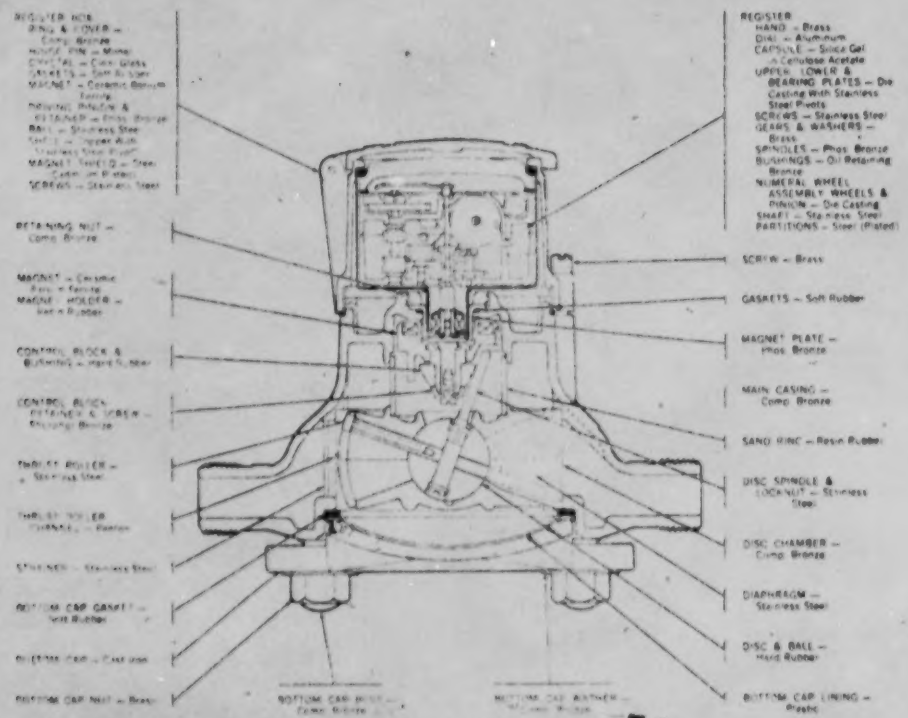

REGISTER
HAND – Brass
DIAL – Aluminum
CAPSULE – Silica Gel
– Cellulose Acetate
UPPER, LOWER & BEARING PLATES – Die Casting With Stainless Steel Pivots
SCREWS – Stainless Steel
GEARS & WASHERS – Brass
SPINDLES – Phos. Bronze
BUSHINGS – Oil Retaining Bronze
NUMERAL WHEEL ASSEMBLY WHEELS & PINION – Die Casting
SHAFT – Stainless Steel
PARTITIONS – Steel (Plated)
SCREW – Brass
GASKETS – Soft Rubber
MAGNET PLATE – Phos Bronze
MAIN CASING – Comp. Bronze
SAND RING – Resin Rubber
DISC SPINDLE & LOCKNUT – Stainless Steel
DISC CHAMBER – Comp. Bronze
DIAPHRAGM – Stainless Steel
DISC & BALL – Hard Rubber
BOTTOM CAP LINING – Plastic

TABLE 1

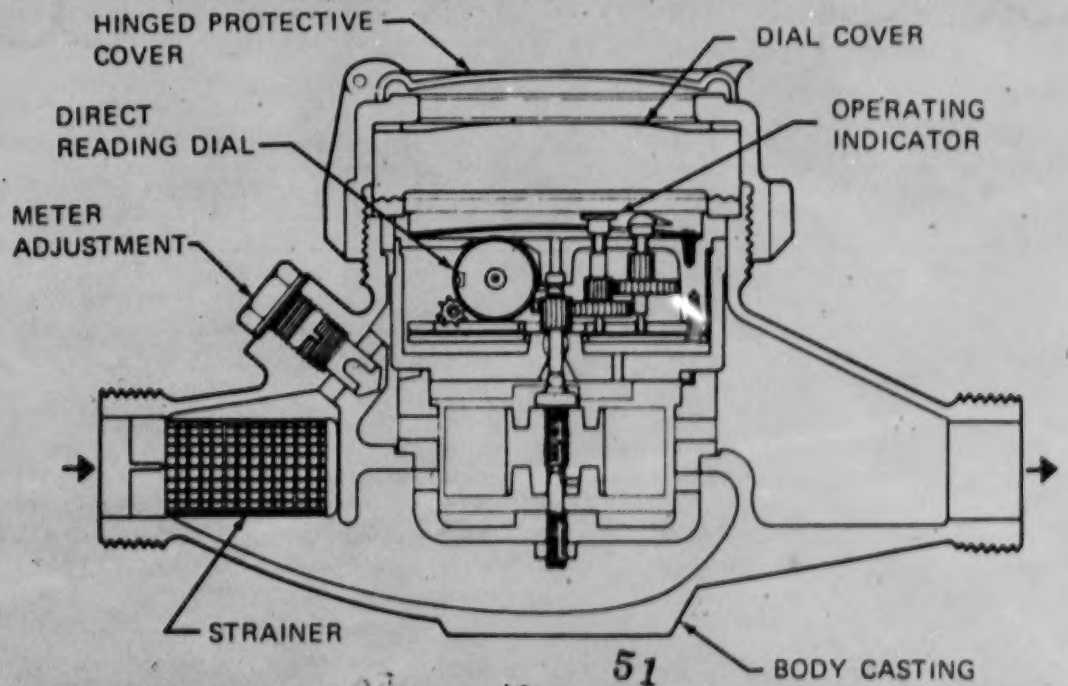
RECOMMENDED CAPACITIES FOR DISPLACEMENT-TYPE SERVICE METERS

Meter Size, Nominal	*Minimum Capacity[a] (gpm)*	*Average Maximum Capacity[b] (gpm)*	*Maximum Instantaneous Capacity[c] (gpm)*
⅝ by ¾	¼	4	20
¾	½	6	30
1	¾	10	50
2	2	32	160
3	4½	60	300
4	8	100	500
6	14	200	1,000

[a] Based on sensitivity—95% registration
[b] Recommended maximum long-term flow rate based on 20% of maximum instantaneous capacity
[c] Based on 15-psi pressure drop across ⅝- by ¾-in. and ¾- and 1-in. meters; 20 psi across 1½-, 2-, 3-, 4-, and 6-in. meters (AWWA specification)

Figure 10

Radial turbine type current water meter.



use: the turbine type and the propeller type.

The basic principle upon which turbine meters operate is the same as that of the hydraulic turbine. A bladed rotor is mounted in a special passage through which the stream is directed. The reaction of the water against the blades of the rotor causes it to rotate at a speed proportional to the velocity of flow. The rotating movement is transferred through a gear train to the meter register.

There are three general designs of turbine rotors. In the first, the water flows through rotor blades in a radial direction, i.e., at right angles to the axis of the rotor. The term "turbine meter" was formerly applied to this particular design. In the second design, the flow is axial or parallel to the rotor axis, and this type is commonly called a helical or axial flow type. In the third type, known as a mixed flow turbine meter, the water flow is partly radial and partly axial. Each of these types have specific advantages and disadvantages that should be given consideration in selecting a meter for a difficult service condition. Turbine meters are used principally to measure relatively high flow rates where the flow range is not excessive and where there is sufficient head available to overcome the friction loss through a turbine meter (see Table 2).

The propeller meter, as commonly designated, is a special type of axial flow turbine meter (see Figure 11). In contrast to the turbine, where the direction of water flow changes appreciably while passing through the measuring element, the water flows straight through the propeller meter. As is apparent, the friction loss in a propeller meter is lower than in the same nominal size turbine meter for the same flow rate. Propeller meters are generally less accurate than turbine meters at the lower rates of flow. Propeller meters are particularly adaptable to mainline metering where it is desirable to keep the friction loss to a minimum, where a high degree of accuracy is not essential, and where the flow range is relatively limited. A propeller meter is generally less expensive than a turbine meter of the same nominal size.

Compound Meters

Where a customer's water use fluctuates regularly over a very wide range, compound meters are used to accurately measure the water consumption. A compound meter is a combination of displacement and current (usually turbine) meters in which the low flow rates are measured by one and the high flow rates are measured by the other (see Figures 12, 13, 14, and 15). In operation, all water flows through the displacement meter until the friction loss across the unit reaches a certain level. At that point, a compounding valve opens permitting flow through the current section of the meter. A compound meter in good repair is capable of accurate measurement (within $\pm$ 2% of actual volume) over an extremely wide range of flow rates with only a slight reduction in accuracy at the point where the compounding valve begins to open. Compound units employing a proportional meter on the main stream and a displacement meter and/or

TABLE 2

RECOMMENDED CAPACITIES FOR TURBINE-TYPE CURRENT METERS

Meter Size, Nominal	*Minimum Capacity[a] (gpm)*	*Average Maximum Capacity[b] (gpm)*	*Maximum Instantaneous Capacity[c] (gpm)*
2	10	53	160
3	15	133	400
4	20	233	700
6	30	533	1,600
8	50	833	2,500
10	75	1,267	3,800
12	100	1,933	5,800
16	200	3,833	11,500

[a] Based on sensitivity—95% registration
[b] Recommended maximum long-term rate based on 33⅓% of maximum instantaneous capacity
[c] Based on 20-psi pressure drop (AWWA specifications)
(There are turbine meters available with higher capacities for same pressure drop.)

Figure 11

Propeller type current water meter.

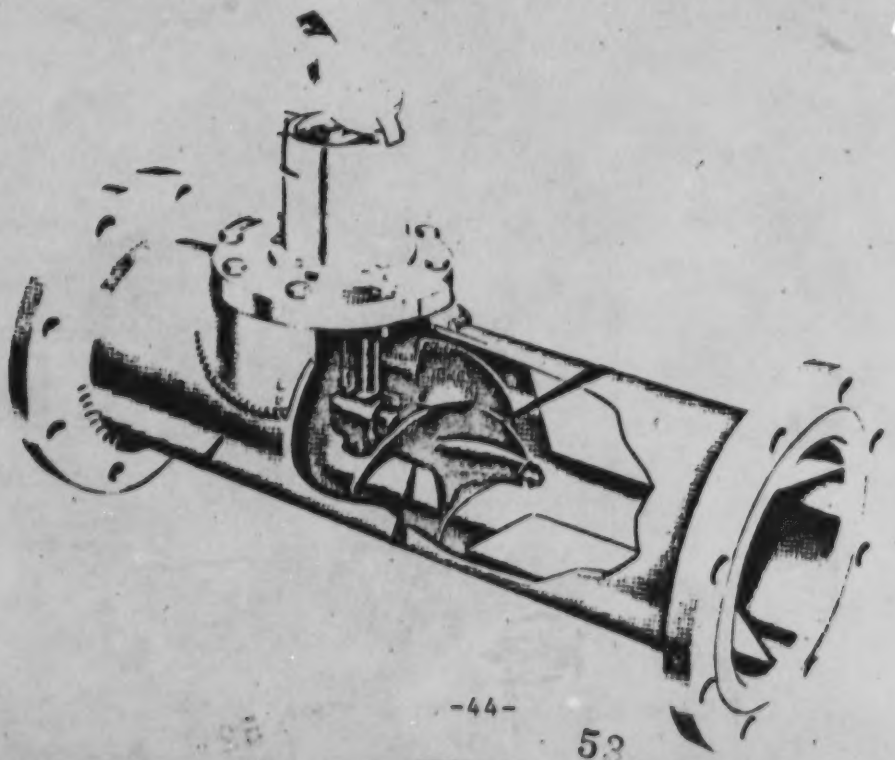


Figure 12

Compound meter with vertical lift check at low flow rates.

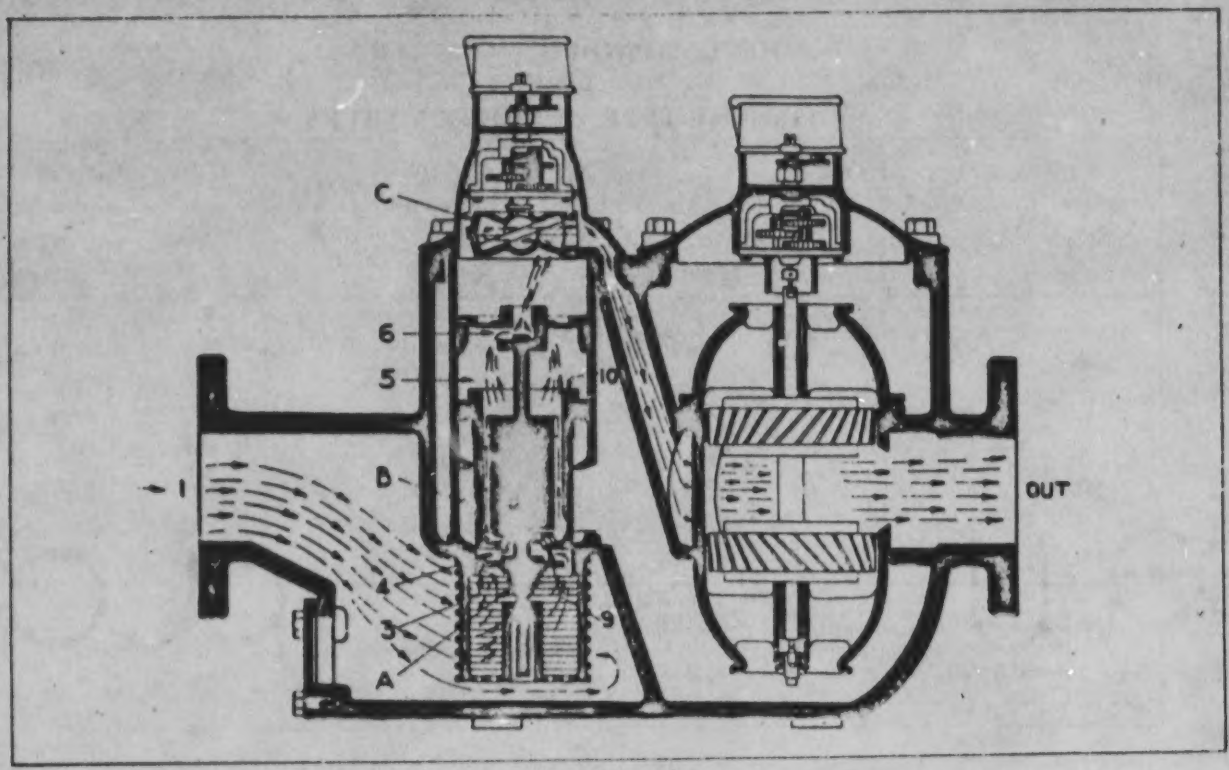


Figure 13

Compound meter with vertical lift check at high flow rates.

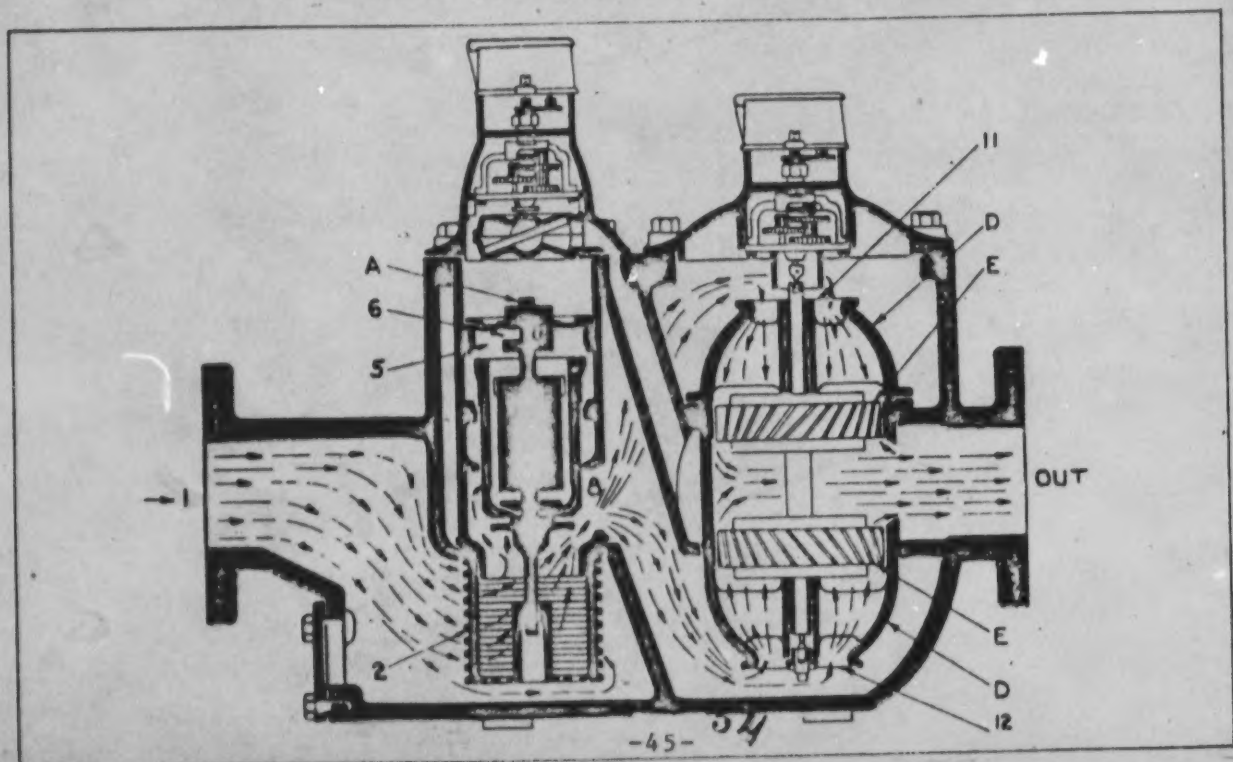


Figure 14

Compound meter with lever arm check at low flow rates.

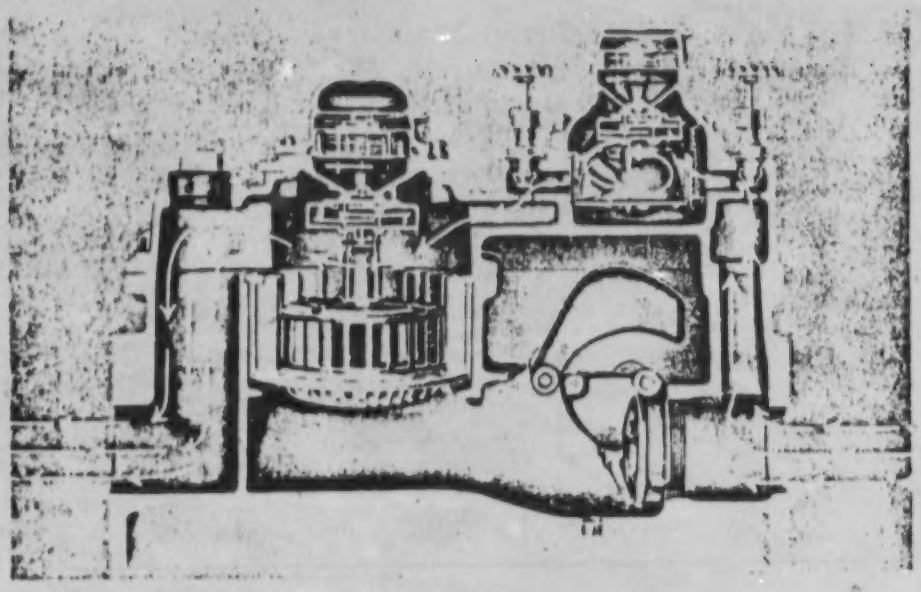
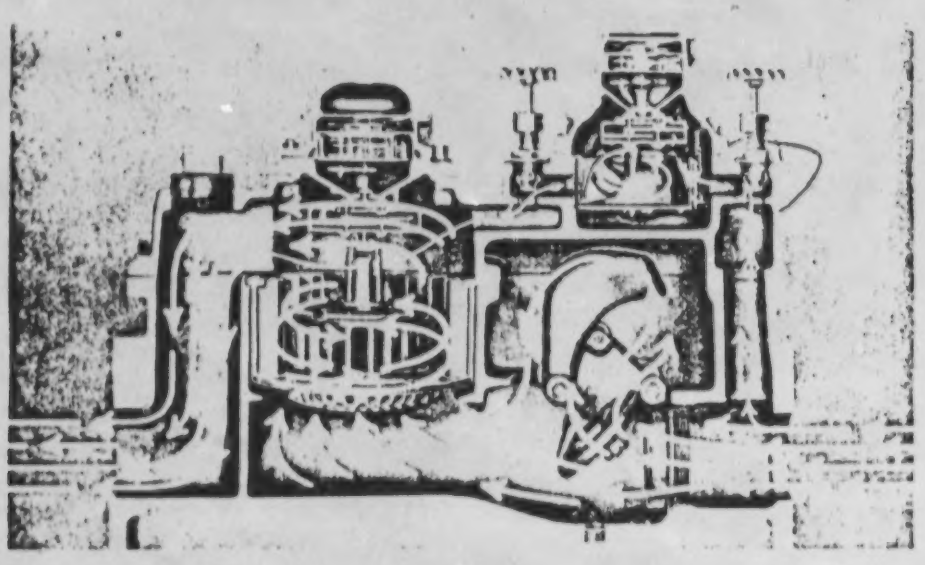


Figure 15

Compound meter with lever arm check at high flow rates.



a velocity meter on the bypass section are available to minimize friction losses at high flow rates and yet maintain very good accuracy over wide ranges of flows.

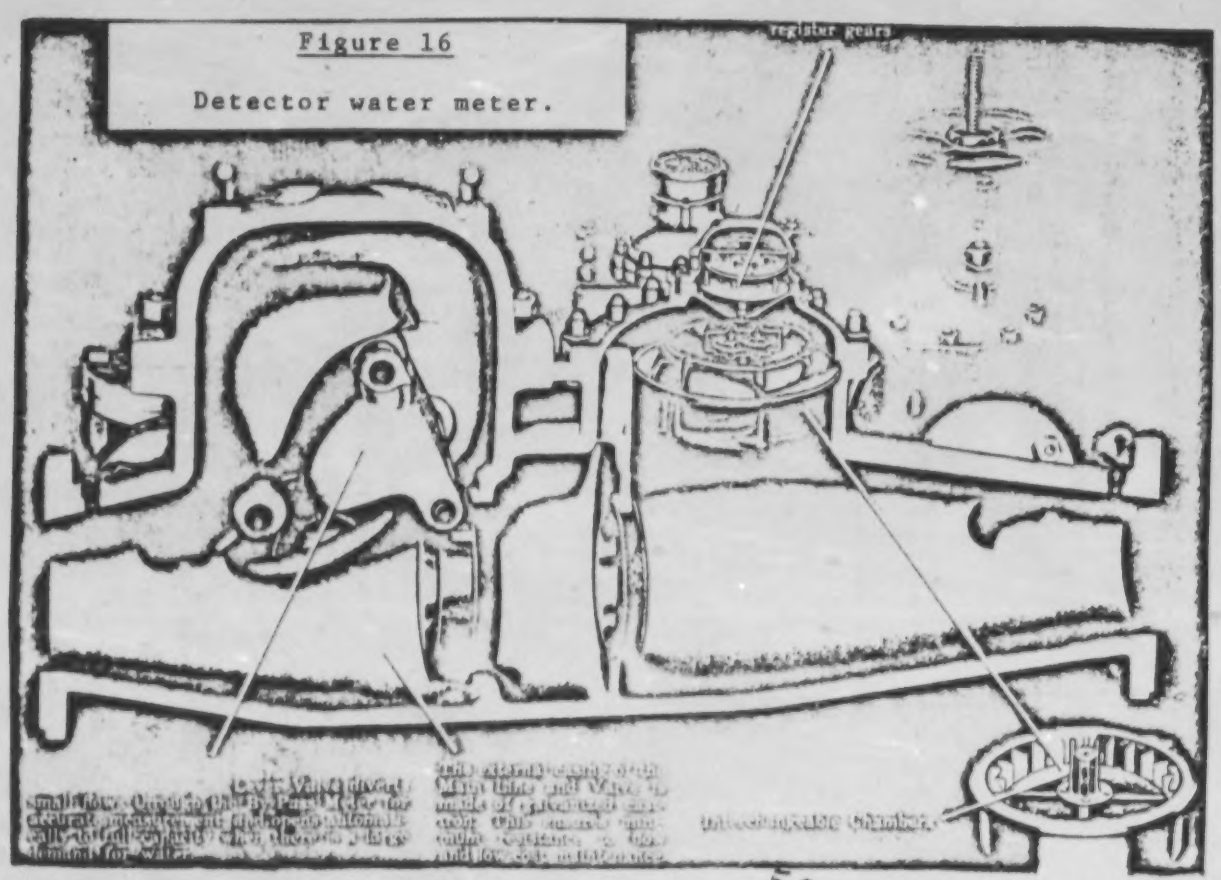
Proportional Meters

Fire services, in which a clear, unobstructed waterway is desired, are frequently metered by proportional meters. A slightly reduced section within the main flow stream (called a friction ring) creates a small pressure drop and forces a quantity of water proportional to the total flow to bypass through a displacement or velocity meter and return to the main flow stream. Proportional meters have low friction losses and have no mechanical parts that, on failure, could restrict fire flows. The meters are less accurate than the other types described, particularly at low flow rates.

One such type of proportional meter is the detector. It is composed of a main-line proportional-type meter with a compound bypass. The mainline meter has a swing check to divert the water through the bypass at low flow. The advantage of this meter is that it will accurately measure a large range of flow rates and provide minimum friction loss through the mainline portion at high flow rates (see Figure 16). This meter would be installed generally in those locations where it is desired to have a single meter that will provide high fire flow and low domestic flow rates.

Figure 16

Detector water meter.



VALVE SUMMARY*

Valve Type	*Common Size Range (in.)*	*Particularly Adapted to*	*Main Advantages*	*Main Disadvantages*
Gate valve	½ to 24	Isolation service in pipe grids.	Low cost in small sizes; relatively low friction loss; fairly good service life; ease of installation.	Higher cost in large sizes; large valves are quite heavy; poor for throttling; should not be used where frequent operation is necessary.
Butterfly valve	3 and up	Isolation and automatic control.	Low cost in larger sizes for normal service pressures; some types have very short lengths.	Higher friction loss than gate valve; must use care in selecting valve, particularly for line-break flow conditions; may cause problems when relining pipe.
Globe valve	½ to 24	Isolation in small sizes; flow control in large sizes.	Simple construction; dependable; can be used for throttling.	High friction loss; very heavy in large sizes; expensive in large sizes.
Ball valve	3 and up	Isolation and throttling.	Dependable; very low friction loss; slow shut-off characteristic minimizes closing surges; ease of operation.	Expensive; very heavy.

*Source: Waterworks Manual-basic, P71-54, Coordinating Council for Occupational Education, State of Washington, 1972, pp. 101-110.

Gate Valves

The most common valve in waterworks systems is the NRS (nonrising stem) double-disc gate valve (see Figure 1). It is reasonably dependable, has an almost unobstructed waterway when open, is very economical in the smaller sizes, and can be installed underground with a minimum of cost.

It is not well adapted for throttling, and frequent operation will cause excessive wear on the seating edges of the discs and guides. Too infrequent operation may cause the valve to "freeze" in one position or become very difficult to operate. Where the water carries even small amounts of sand or silt periodically, the valve seats may fill with deposited material unless operated at more or less regular intervals to keep the seats clear. Figure 2 shows various types of wedging mechanisms found in gate valves. For 12-in. and smaller pipelines, gate valves are in most instances the best choice for underground distribution service. Large gate valves (14 in. and larger) generally are equipped with small bypass valves to reduce pressure differentials upon opening and closing. Large valves are usually equipped with spur or bevel gearing to reduce the labor of operation. In the larger sizes, it may be impractical to install a valve in the common vertical position because of height limitations. In such cases, gate valves are installed with their stems horizontal and the valves are geared so the axis of the operating nut is vertical. A gate valve to be installed in a horizontal position should be equipped with rollers and tracks to carry the weight of the discs (see Figure 3).

Until the advent of the O-ring seal, a few years ago, the seal between the operating stem of the gate valve and the valve bonnet was effected with packing in a packing gland held tight by a bolted connection. Leakage around the packing was not uncommon, particularly after the valves had been in service several years. Tightening the packing nuts or replacement of the packing is difficult and oftentimes costly as excavation is usually necessary. The O-ring seal is, in this regard, a decided improvement in the design of gate valves (see Figure 4). While the O-ring seal gate valve is relatively new and its actual life has not yet been definitely established, accelerated tests indicate it will outlast the average packing.

Gate valves are available with bell-and-spigot, flanged, mechanical joint, or slip-on joint ends as stock items and can be furnished with a different joint type on each end on special order. It is frequently economically advantageous to use a flange-by-mechanical joint, flange-by-slip-on, etc., as the auxiliary valve on a fire hydrant assembly rather than a flanged valve and an adapter or some other similar combination (see Figure 5).

Globe and Angle Valves

Except for special service applications, the globe valves used in water distribution systems are generally 3 in. and smaller. The

Figure 1

Typical gate valve.

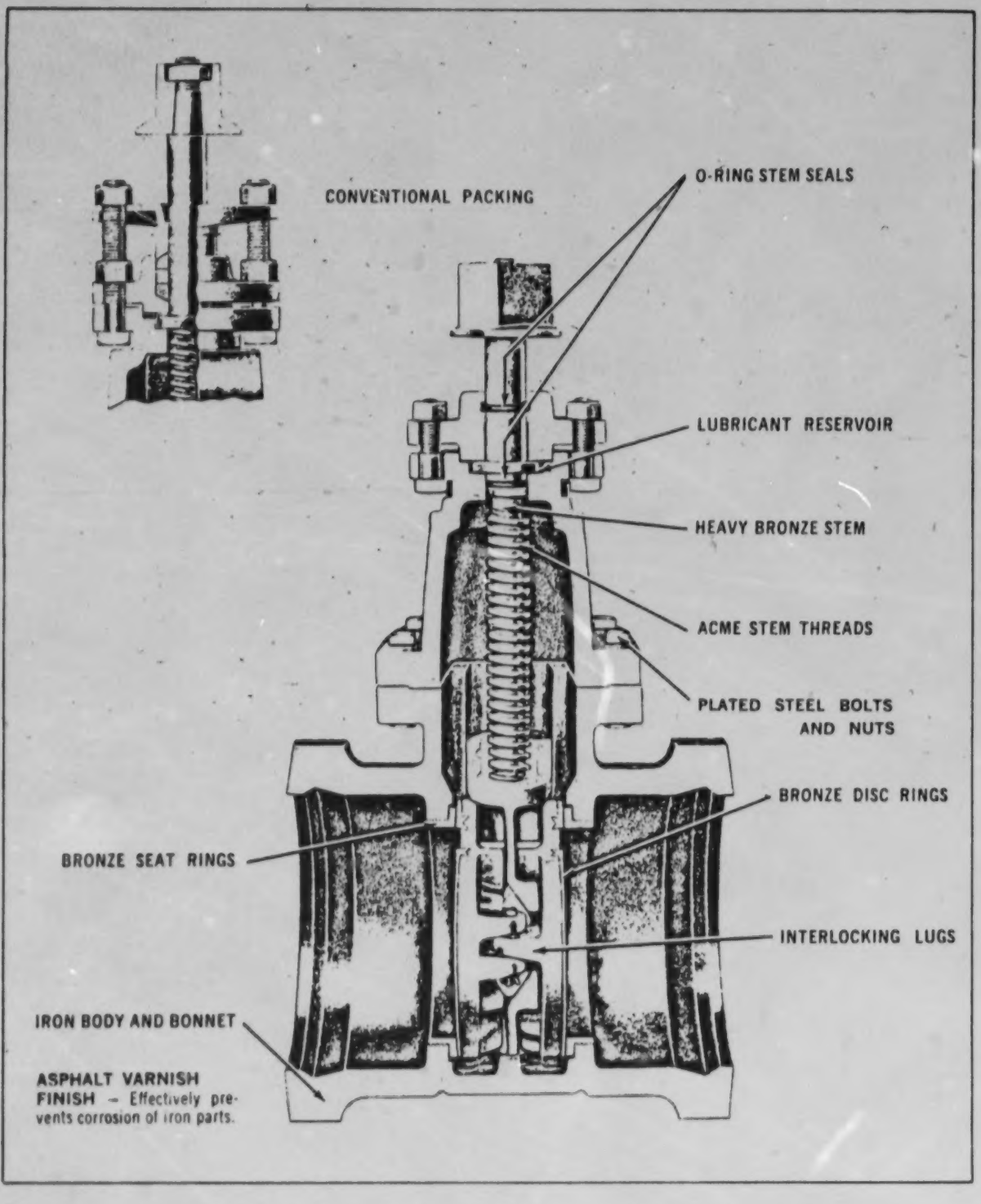
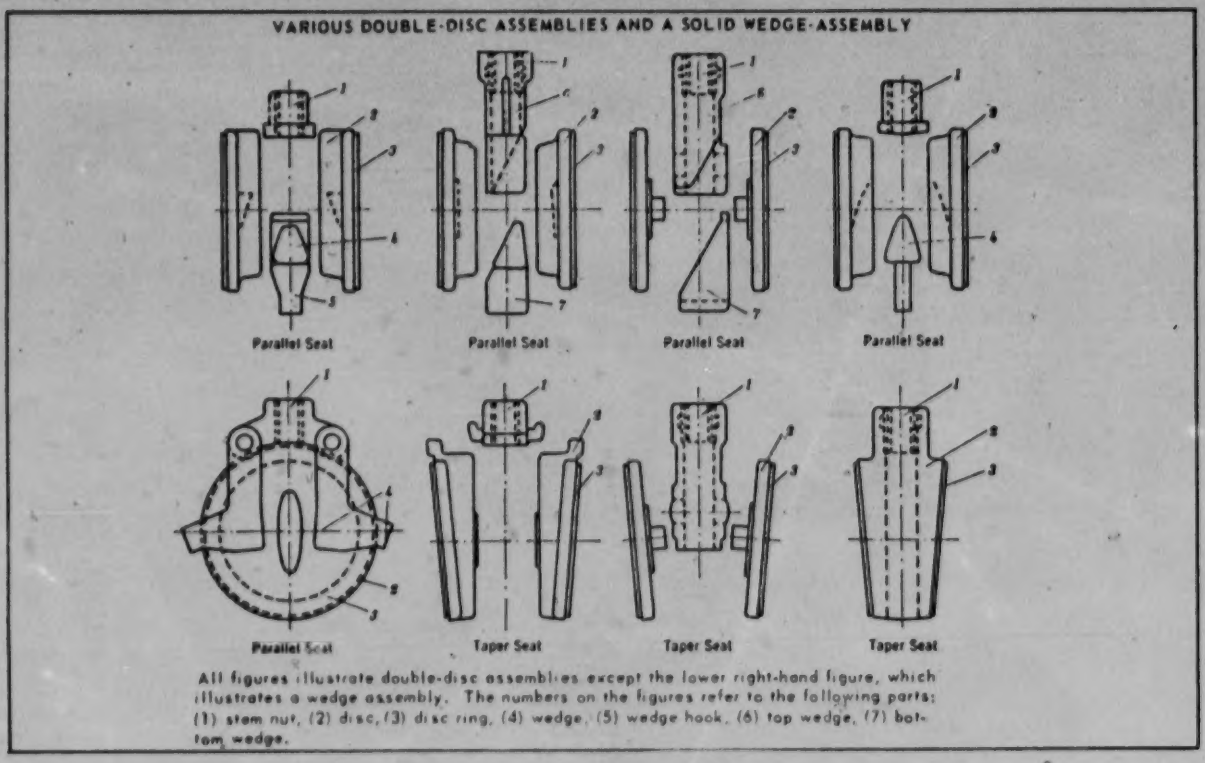


Figure 2

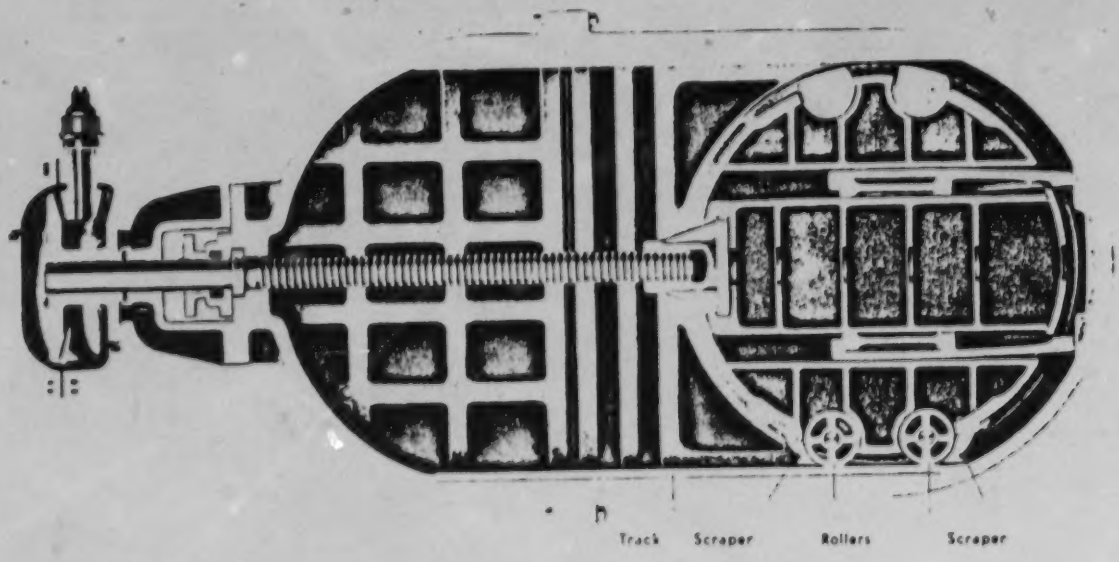
Gate valve wedging mechanism.



All figures illustrate double-disc assemblies except the lower right-hand figure, which illustrates a wedge assembly. The numbers on the figures refer to the following parts: (1) stem nut, (2) disc, (3) disc ring, (4) wedge, (5) wedge hook, (6) top wedge, (7) bottom wedge.

Figure 3

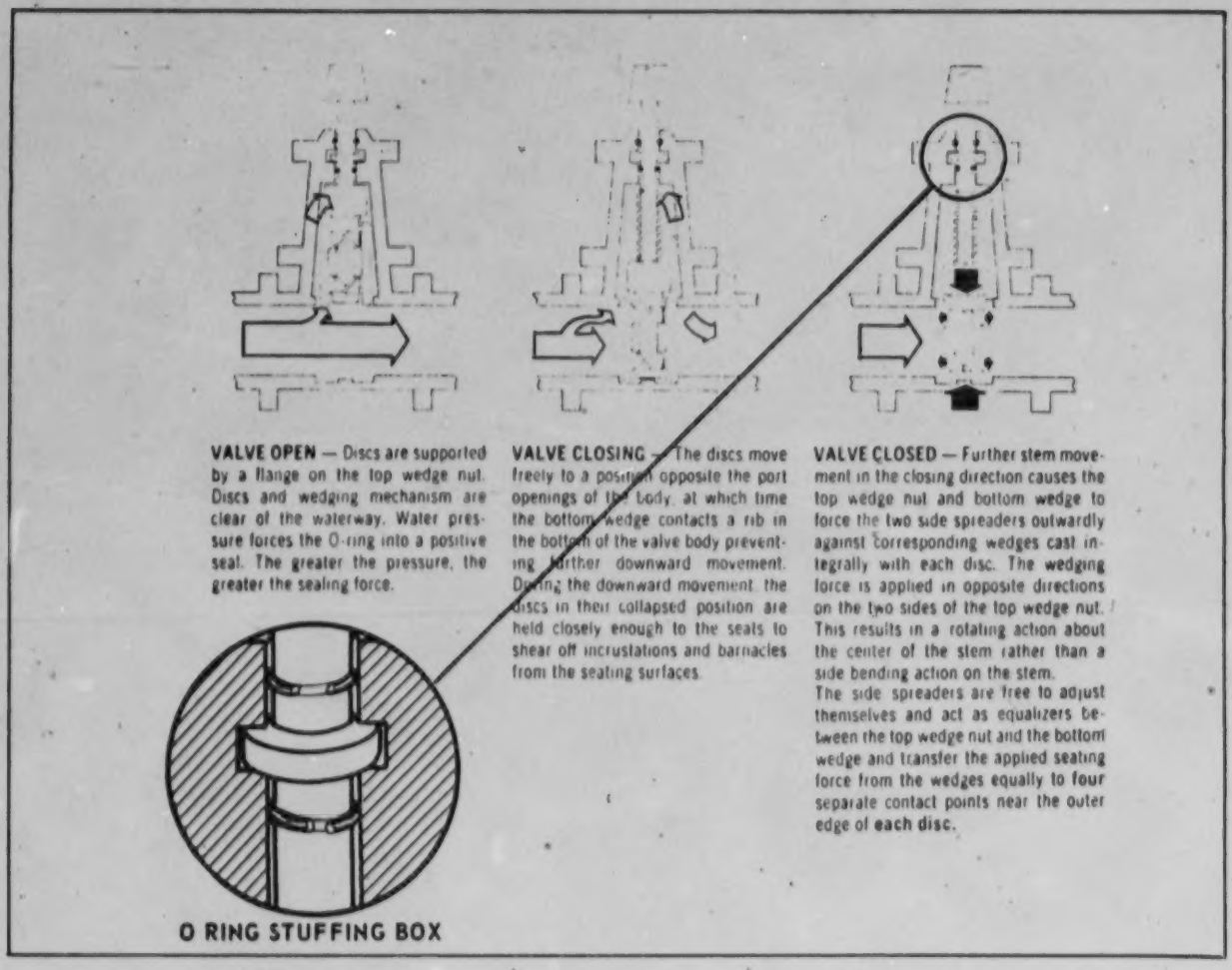
Laydown type gate valve.



Valve equipped with tracks, rollers, and scrapers, for installation in a horizontal position in a horizontal pipe line.

Figure 4

Principles of operation of a gate valve showing O-ring stuffing box.


VALVE OPEN — Discs are supported by a flange on the top wedge nut. Discs and wedging mechanism are clear of the waterway. Water pressure forces the O-ring into a positive seal. The greater the pressure, the greater the sealing force.
VALVE CLOSING — The discs move freely to a position opposite the port openings of the body, at which time the bottom wedge contacts a rib in the bottom of the valve body preventing further downward movement. During the downward movement the discs in their collapsed position are held closely enough to the seats to shear off incrustations and barnacles from the seating surfaces.
VALVE CLOSED — Further stem movement in the closing direction causes the top wedge nut and bottom wedge to force the two side spreaders outwardly against corresponding wedges cast integrally with each disc. The wedging force is applied in opposite directions on the two sides of the top wedge nut. This results in a rotating action about the center of the stem rather than a side bending action on the stem. The side spreaders are free to adjust themselves and act as equalizers between the top wedge nut and the bottom wedge and transfer the applied seating force from the wedges equally to four separate contact points near the outer edge of each disc.
O RING STUFFING BOX

relatively high friction loss and comparatively high cost limit use of globe valves, for on-off service, to the smaller sizes. In essence, a globe valve operates by forcing a tapered plug into the port through which the water flows (see Figure 6).

An angle valve is a globe valve in which the entrance and exit ports are at right angles to each other. Globe valves are most commonly used with screwed pipe connections and consequently find widest use in water distribution service in conjunction with small-diameter steel pipe or plastic pipe.

Large globe and angle valves are used frequently for throttling and control functions such as pressure-reducing valves, altitude valves, check valves, and many other special-purpose applications. The larger globe valves are normally joined by flanged connections (see Figure 7).

Figure 5

Connections available on gate valve.

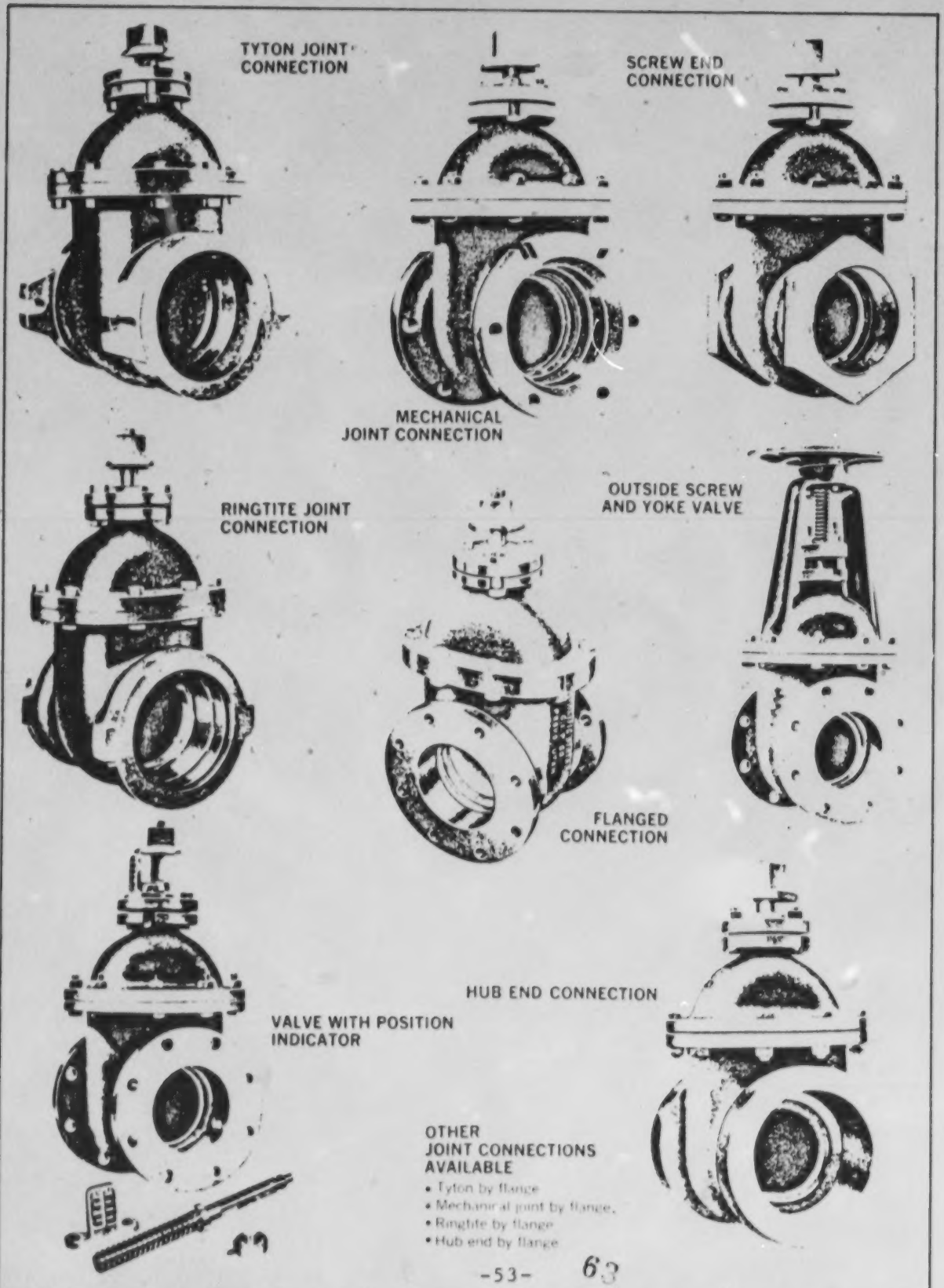
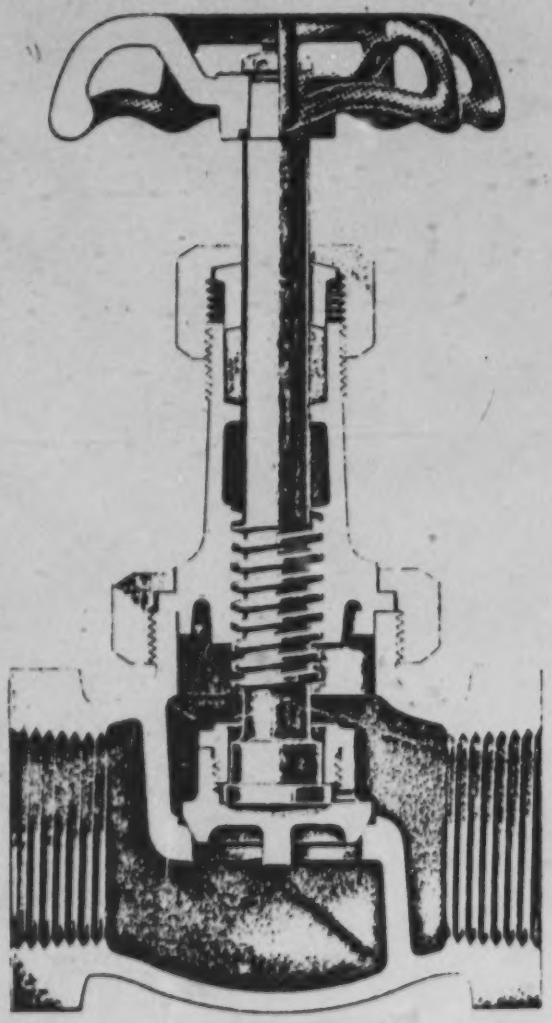
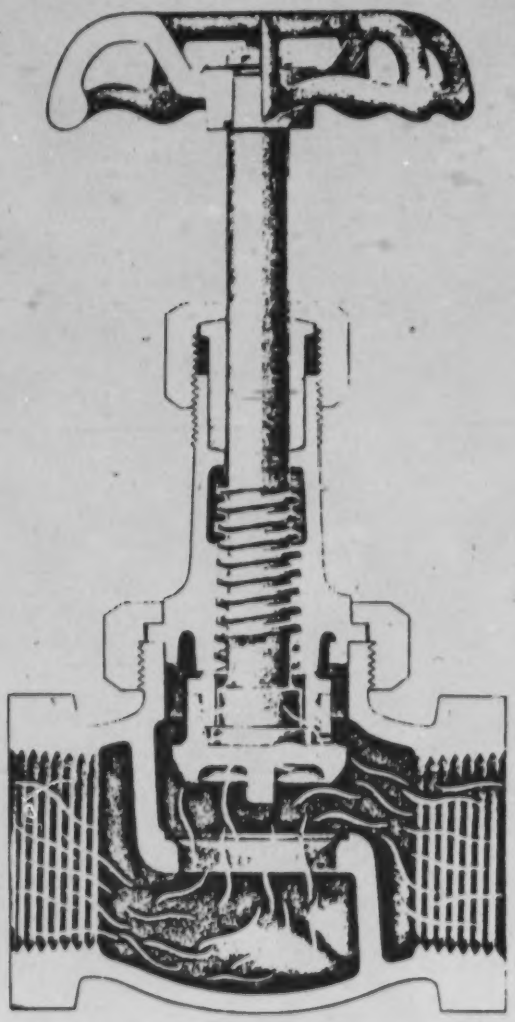


Figure 6

Globe valve.



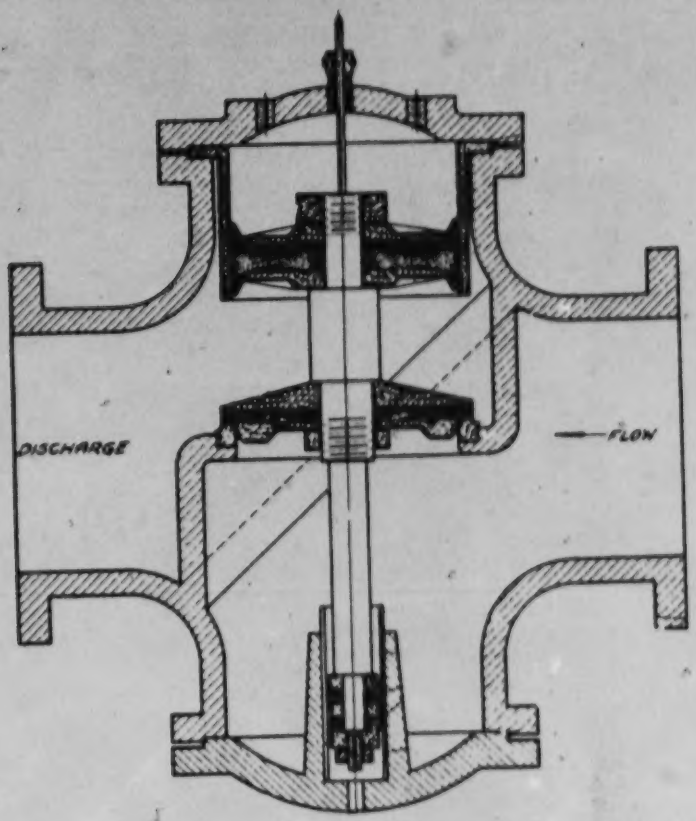
Completely closed globe valve stops flow. This requires fewer turns of the handwheel compared to gate valves. Thus, globe valves are best for throttling and also require less work. Fewer turns in globe valve operation means less wear on parts, longer valve life.



Typical globe valve construction demonstrates how seating is parallel to the line of flow as opposed to vertical seating in gate valves. This design makes globe and angle valve best for throttling. Actual flow is thus perpendicular to the line and consequently meets greater resistance. Therefore, if pressure drop is objectionable in the line, globe valves should not be used. The cross section view also shows that flow starts immediately at turn of the handwheel to open. This flow is proportionate to the degree of the opening. This degree is determined by the number of turns of the handwheel. If four turns open the valve completely, one opening turn means 25% flow, etc.

Figure 7

Globe valve for pressure regulating applications.



Butterfly Valves

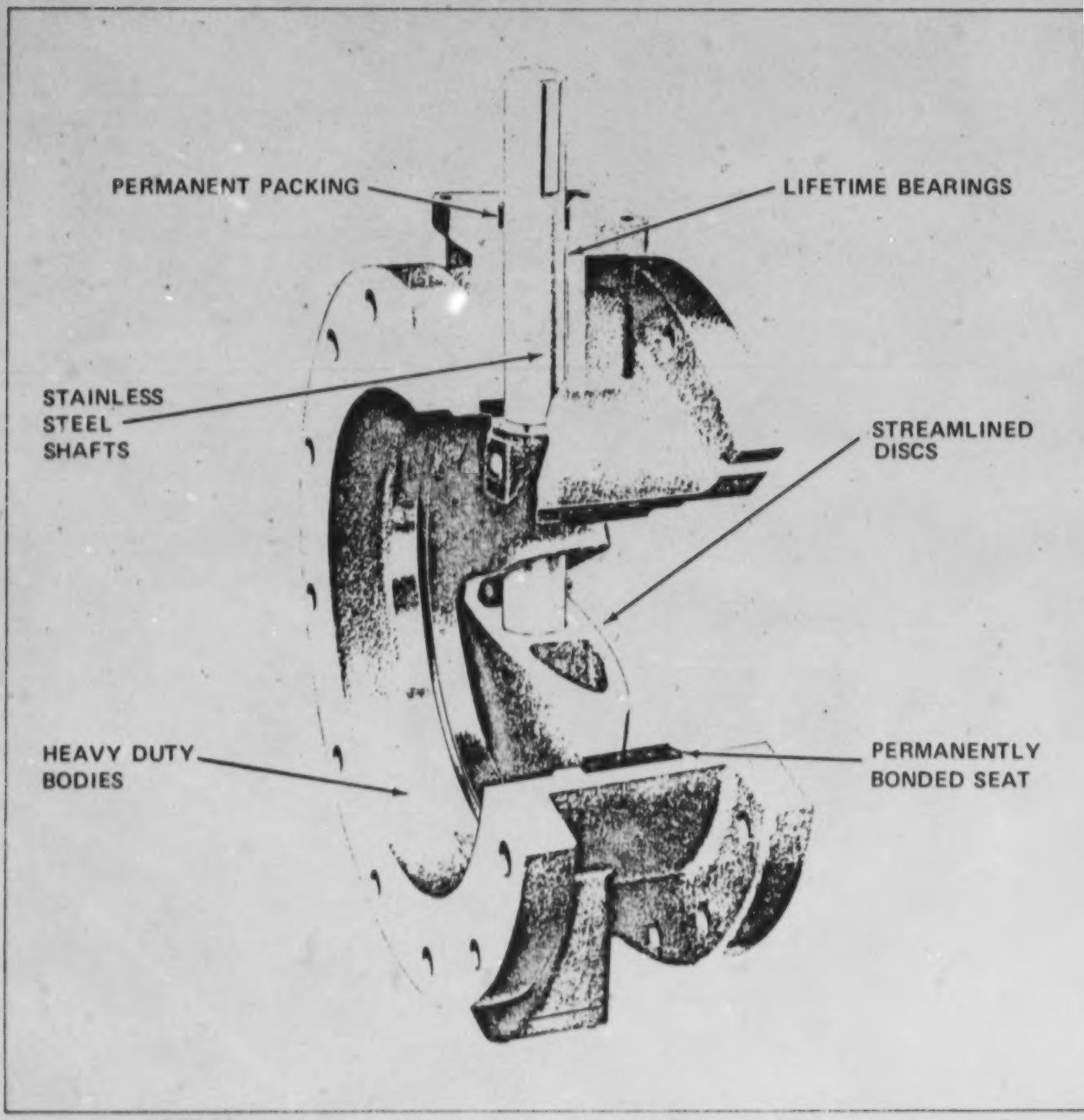
Rubber-seated butterfly valves are particularly adapted to certain service conditions in waterworks facilities (see Figure 8).

The butterfly valve consists of a shaft-mounted disc that rotates 90° from full open to full closed. When the disc is rotated into the closed position, it compresses the rubber seat, which is slightly smaller in diameter than the disc, and a tight seal is made. Since the valve shaft rotates only 90° from the open to the closed position, some type of gear or lever is used to control the speed of operation and aid in maintaining a partially open or closed position. For buried service, the gear assembly must be enclosed; this type of operator is in common use.

Although butterfly valves, particularly in the larger sizes, are frequently used for on-off service in place of gate valves, the butterfly is also used in throttling or automatic control of the flow of water. The valve will open, close, or throttle on command from a water level, pressure, temperature, rate of flow, or other functional signal from the controlling point. Electric motor,

Figure 8

Butterfly valve.



hydraulic or pneumatic cylinders, and pneumatic diaphragms are the most common types of operators for automatically controlled conditions.

Other Types of Valves

There are many other types of isolating valves in use in waterworks systems, including ball valves, plug valves, and special-purpose valves such as check valves, mud valves, shear gates, sluice gates, and flap gates.

Hydrants

The purpose of a fire hydrant is to provide a quick, simple, and dependable method of connecting a fire hose to a source of water under pressure. Post-type fire hydrants for ordinary waterworks service are commonly of two basic types; the compression type, which opens against the flow, and the toggle joint or Corey type, which opens with the flow. The pipe connection from a compression type hydrant is at the bottom of the hydrant, whereas the pipe connection from a Corey type hydrant is roughly a foot above the bottom of the hydrant. When installed, the two types can be distinguished by the location of the operating nut; the operating nut on the compression hydrant is in the center, whereas the Corey hydrant's operating nut is off-center.

The size of the hydrant refers to the size of the main valve opening, either 4-, 5-, or 6-in. nominal diameter. Hydrants can be furnished with one to four 2½-in. hose nozzles and one or two 4-in. steamer nozzles. The most popular combination is a 5-in. hydrant with two hose nozzles and one steamer nozzle. The length of the hydrant is described as the "depth of bury" and is the distance from the ground line to the bottom of the pipe connection, usually in 6-in. increments.

The hydrant barrel is of cast iron and the wear points are of bronze, principally. Hydrants meeting Fire Underwriters' requirements are designed so that the main valve will remain closed if the barrel is broken off. Most hydrants manufactured today are provided with breakaway parts at or near the sidewalk flange so that a broken off hydrant can be repaired with only minor replaceable parts.

Hydrants are furnished with hub, mechanical joint, or flanged bottom connections. Hose and steamer nozzle threads can be provided to correspond to the standard of the fire department in the area where the hydrant is to be installed. There are many different nozzle threads; National or American Standard are the most common.

VALVE MAINTENANCE*

Air-relief Valves

Air-relief valves are often installed at crests of sharp hills to allow accumulated air to escape automatically from mains. Otherwise, accumulated air might occupy enough of the pipe to restrict or stop flow when pressure is low.

a. *Dismantle Valve.* Remove air relief valves from the main for complete inspection and servicing.

(1) Check float for leakage.
(2) Check linkage and pins for freedom from corrosion.
(3) Clean orifices.

b. *Check Valve Vault or Manhole:*

(1) Observe condition of masonry, particularly above frost line, and make necessary repairs.

(2) Check steps for soundness.

(3) Inspect manhole cover and top. Check wooden or concrete covers for soundness of frame mounting on masonry. Check seating of covers for proper bearing. Check grade of covers; raise where necessary to keep excessive surface water or earth from entering manhole or vault.

Altitude- and Pressure-Regulating Valves

a. *General:*

(1) Automatic altitude valves in inlet lines are used to keep stand-pipes and elevated tanks from overflowing. When water level reaches the desired maximum height, the valve closes automatically by one of three methods:

(a) Water pressure against diaphragm overcomes set opposing -spring pressure and opens pilot valve, admitting water to hydraulic cylinder of altitude valve and closing valve.

(b) A float is moved by rising water, operating an electric switch which actuates a solenoid pilot valve, admitting water to close altitude valve.

(c) A float is moved by rising water, operating the pilot valve by connecting cable or rods and admitting water which closes the altitude valve. By using different combinations of

*Source: Maintenance and Operation of Water Plants and Systems, Dept. of the Air Force, Air Force Manual No. 85-13, June 1968, pp. 461-481.

pilot controls, the altitude valve can be made to open only at predetermined reduced line pressure, to close in case of unusual draft on the distribution system such as that caused by a broken main, or to close prematurely in case pressure on the system is raised abruptly to provide water for fire fighting.

(2) Pressure-regulating valves, also known as pressure-reducing valves, are used to prevent excessive pressures at low-elevation sections of post distribution systems. Because many types of automatic valves and control equipment are used, specific operating and maintenance instructions cannot be included here; they should be obtained from the manufacturer for each valve in service. The following is only an illustrative schedule.

b. *Test and Grease Pilot Control.* Change pilot control momentarily to induce operation of valve, and then return control to original setting. Grease pilot-setting threads with WP. To close an open altitude valve, back off nut on diaphragm spring-tension setting one or two turns. Return nut to its exact position after inspection.

c. *Service Ross Automatic Valve.* When Ross automatic valve (Figure 1) is to be opened, external control shuts off power water and vents chamber K to the atmosphere. Then pressure inside main valve lifts up piston, raising valve disc from its seat. To close valve, power water is automatically supplied to chamber K by external control valve. Although pressure inside valve may be same as power water pressure, valve closes because lower part of cap cylinder (23) is vented to atmosphere. Equivalent area above upper piston is greater than area below this piston.

(1) Disassemble and inspect. Remove top cap. Withdraw stem for inspection.

(2) Clean valve of all sediment.

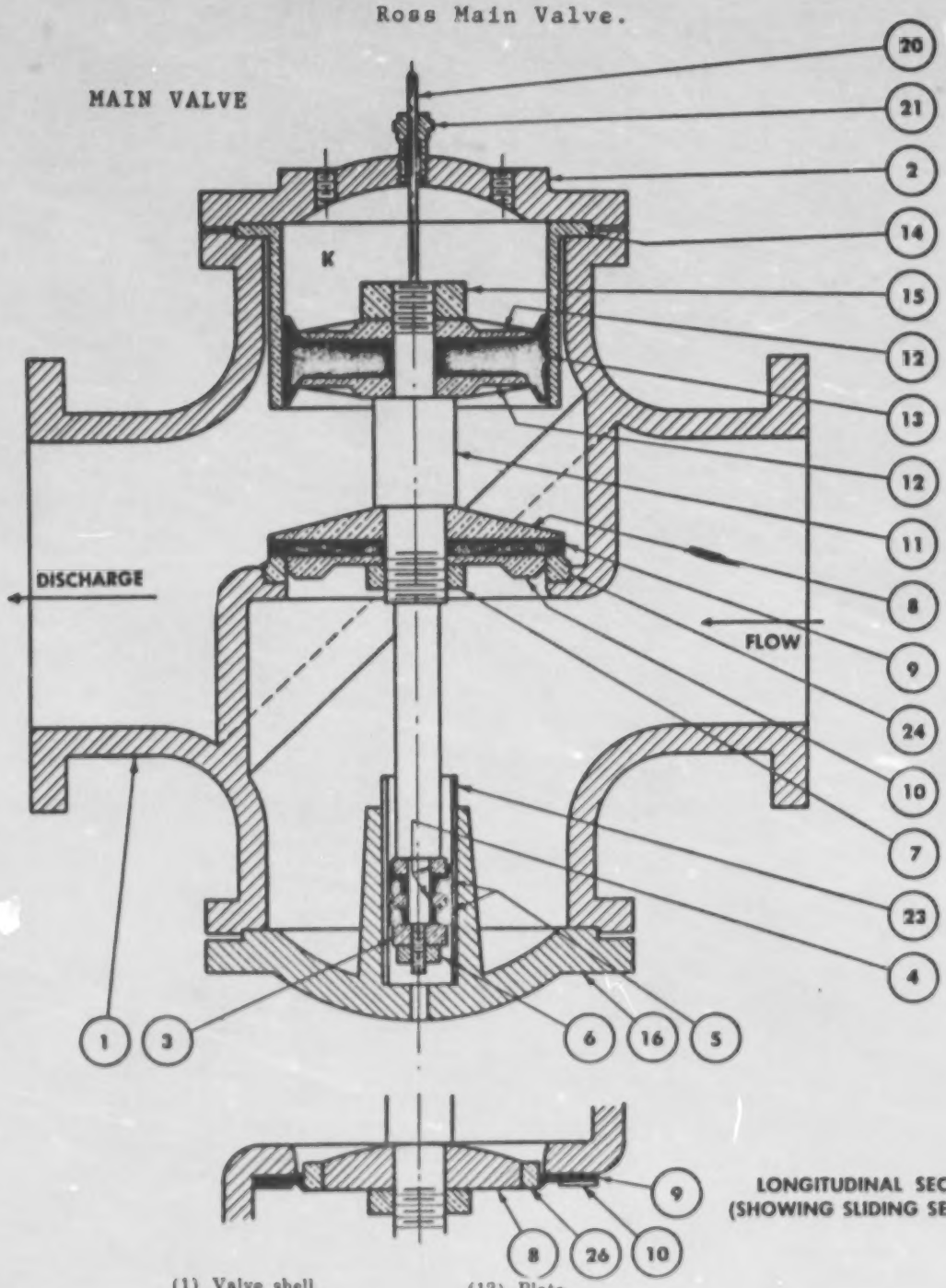
(3) Replace worn cup leathers. Leakage occurs through vent below (6) when bottom cup leathers are worn. Worn seat leathers permit leakage through main valve. Leakage past main cup leathers may also indicate improper valve functioning. Leathers may last 4 to 10 years.

d. *Service Anderson and Golden-Anderson Valves.* Globe-pattern valves (Figure 2) are closed by discharge of water at line pressure through port (1) above sliding piston (2) which forces piston down to its seat. To open, pressure above piston (2) is reduced as pilot valve closes off pressure water and vents port (1) to atmosphere. Line pressure beneath piston (2) forces piston up.

(1) Dismantle valve. Remove valve lid covering piston chamber. Withdraw piston.

Figure 1

Ross Main Valve.



LONGITUDINAL SECTION
(SHOWING SLIDING SEAT DISC)

(1) Valve shell.
(2) Top cap.
(3) Bottom stem guide nut.
(4) Bottom cup follower.
(5) Bottom piston-cup leather.
(6) Bottom stem locknut.
(7) Nut.
(8) Seat disk.
(9) Seat leather.
(10) Seat-leather support.
(11) Stem.
(12) Plate.
(13) Main cup leather.
(14) Main bushing.
(15) Top nut.
(16) Bottom cap.
(20) Indicator rod.
(21) Indicator stuffing box.
(23) Cap cylinder.
(24) Seat ring.
(26) Disk ring.

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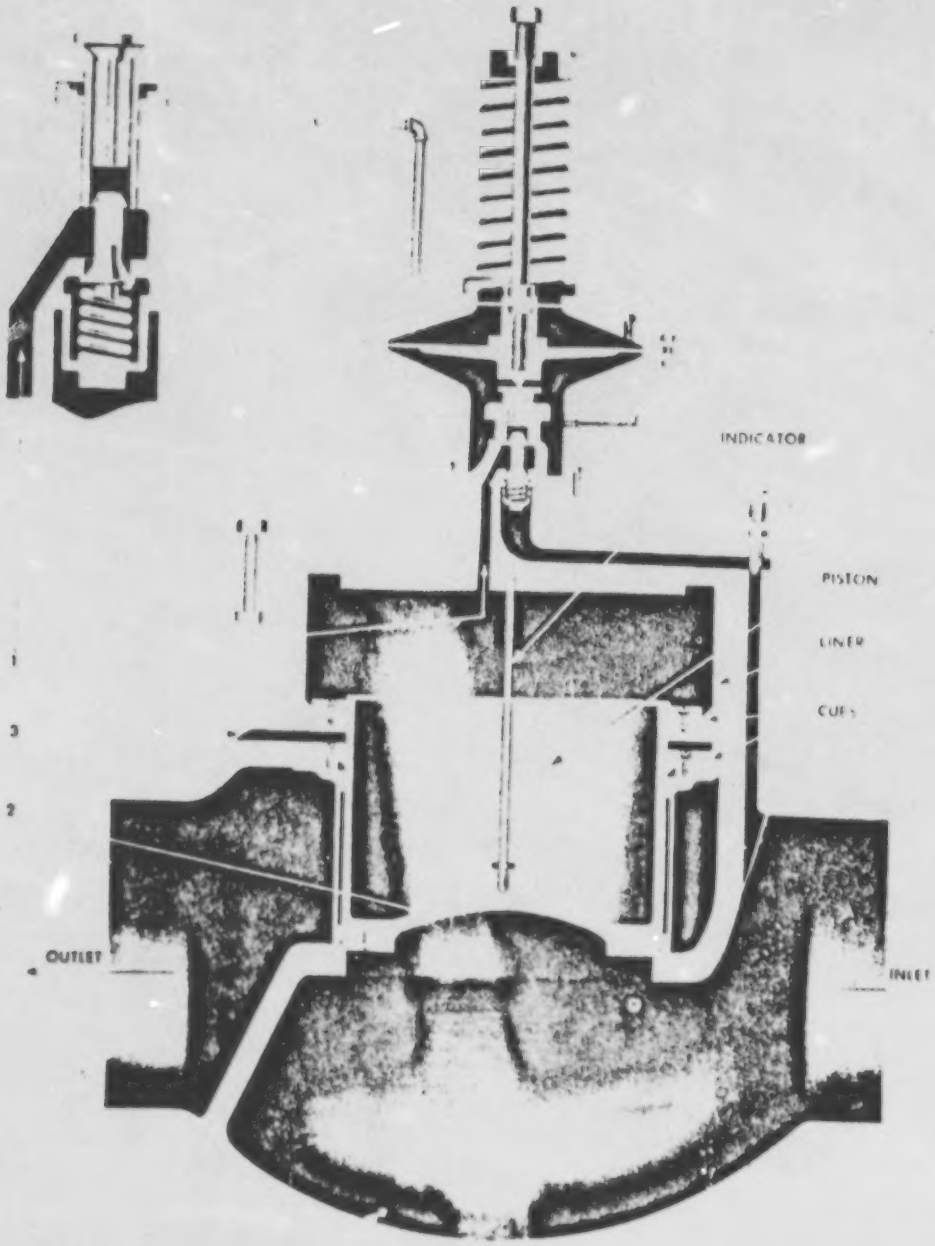
Figure 2

Globe-Pattern Single-Acting
Automatic Valve.



(2) Inspect walls of piston and cylinder lines for scoring. Smooth and polish with fine emery cloth.

(3) Inspect leather piston and liner cups and piston seat. Replace if necessary. Leathers may last from 4 to 10 years.

(4) Check for leakage. Keep port (3) open at all times. Leakage here indicates worn cup rings or scored piston or liner surface. Constant leakage from pilot waste lines indicates defective pressure valve, which must be reground and replaced. Leakage through main valve indicates worn leather seat rings.

Cone-plug Valves

Cone valves with full round way openings are supplied by several manufacturers in 4-inch and larger sizes. The cone plug is seated against the valve body in both open and closed positions. While operating, the plug is lifted off its seat, revolved, and reseated by a hydraulic cylinder which is pilot-actuated or manual. Because of the many kinds of pilot controls used for altitude, check, pressure regulation, and pressure relief, specific operating and maintenance instructions should be obtained from manufacturer for each cone valve in service.

a. *Lubricate.* Operate each cone valve by uncoupling pilot valve linkage and moving pilot control manually or by changing pilot control setting momentarily.

(1) Grease or oil metal-to-metal contacts in pilot mechanism.
(2) Oil packing glands.
(3) Grease or oil all parts of seating and rotating mechanism.

b. *Dismantle and Service.* Remove all corrosion on plug or valve body. Clean with wire brush and paint inside and out with two coats of good corrosion-resistant paint. Corrosion or tuberculation on plug or inside valve body prevents tight seating and causes wire-drawing and seat corrosion.

Hydraulic-Cylinder-Operated Valves

a. *Inspect and Lubricate.* Check hydraulic cylinder while valve is put through an operating cycle.

(1) Oil packing around piston rod and telltale rod. Tighten if leakage is found.

(2) Replace packing when normal pressure on gland does not stop leak.

(3) Check waste-line discharge. When waste line continually discharges water in either open or closed position, dismantle cylinder and check piston-cup leathers for wear.

b. *Dismantle Cylinder and Piston:*

(1) Remove scoring of cylinder liners with fine emery cloth.

(2) Check condition of cup leathers.

(3) Check condition of piston and telltale rods, especially where they contact packing. Polish out any scoring.

(4) Clean cylinder heads and piston surfaces of all corrosion. Apply two coats of protective paint to all iron surfaces.

Valve-Pilot Controls

Valves operated by hydraulic cylinders, automatic valves with internal cylinders, or equivalent mechanisms are usually actuated by manual, diaphragm, or electric-operated pilot valves. Observe pilot control during one or more cycles to check for proper operation.

a. *Lubricate and Check Leakage:*

(1) Oil pins and linkage.

(2) Grease exposed threads on adjustment rods.

(3) Oil packing glands. Remove corrosion which might cause friction.

(4) Check for leakage past valve seats or through ruptured diaphragm. Repair where necessary.

b. *Dismantle and Inspect Pilot-valve Assembly:*

(1) Grind or replace valve seats when seats show pitting or leakage.

(2) Clean all strainers in control-piping lines.

(3) Check diaphragms. Look for signs of possible failure such as cracking or separation of fabric layers.

Gate Valves (Buried)

a. *General.* Distribution system gate valves are generally known as nonrising stem, inside screw, solid wedge, or double disk gate valves. They are usually equipped with 2-inch-square operating nuts and, although sometimes located in vaults or manholes, are usually covered and protected with adjustable height, cast-iron roadway boxes about 6 inches in diameter. To make sure each valve is instantly serviceable, periodic inspection and prompt repair are required. There are three common sources of trouble:

(1) Valves cannot be located in an emergency.

(2) They cannot be operated because maintenance has not been performed.

(3) They are covered up, or obstructed, or valve boxes are pushed sideways by roadgraders, or filled with foreign matter.

b. *Finding Valves.* Keep pertinent gate-valve physical data records in an indexed looseleaf valve book. Include a sketch or drawing for referencing each valve, showing location of permanent reference structures where necessary. Mount master file of valve maintenance record cards in valve book. Make copy of book available to maintenance crew. To assist in locating lost valves, carry a dip needle or miner's compass in service truck. A mine locator can also be used to locate valve boxes.

c. *Inspect and Service Valves:*

(1) *Note Whether Valve is Found Open or Closed.*

(2) *Check Operation.* Where possible check operation by closing valves completely and then opening them. If installation requirements would be affected by completely closing valves such as those on primary transmission mains or deadend mains, do not close them completely unless specific arrangements are made to meet installations needed from another source. To inspect, almost close such valves, then open them.

(3) *Check and Lubricate Packing.* Dry packing is shown by difficult operation at all points of valve movement. To moisten and lubricate dry packing, pour half-and-half mixture of kerosene and lubricating oil down a ½-inch pipe, bent at bottom to touch stem below operating nut. If packing leaks, dig up valve and tighten packing. If necessary, replace packing, opening valve as much as possible and pulling stem shoulder tight against bonnet to prevent excessive leakage during the operation.

(4) *Check for Bent Stem.* Bent stems allow comparatively free operation when valve is nearly open or closed but cause considerable binding in middle portion of travel. Replace stem without shutting down other valves. Close valve tightly. Remove stuffing-box assembly and unscrew stem from stem nut. Insert new stem, reassemble stuffing box, and repack valve.

(a) Broken or stripped stems or stem nuts permit unlimited turning of valve stem. If found, remove pressure from main, open valve, and repair. If new parts are not available, remove gate and stem and drive tapered softwood plug into stem opening from inside of bonnet. Replace working parts after repair parts have been obtained.

(b) Injury to valve stems usually results from using too much force when trying to close gates which are kept from seating

by foreign matter, scale, or corrosion under the seat in the lower part of the body. To prevent this, open valve a few turns after first closing it, and admit a good flow of water under gate to wash out loose material. After repeating operation four or five times, a reasonably tight closure can usually be made.

(5) *Check Operating Nut.* Replace missing or badly chewed operating nuts.

(6) *Check and Lubricate Gears.* Observe and correct any bad operating condition. Grease gears with manufacturer's recommended lubricant.

(7) *Check Bypass.* Note whether bypass is open or closed and whether small valve is operating satisfactorily.

(8) *Check Condition of Box or Vault.* Adjust box or vault if buried or protruding. Reset if box is too close to stem. Check cover and replace if missing or broken. Loosen wedged, tarred, or grouted-in cover. Clean box of debris, sand, and dirt above packing gland.

Gate Valves (Not Buried)

Most common maintenance required by unburied gate valves is oiling, tightening, or replacing stem stuffing-box packing.

a. *Oil Packing.* To eliminate excessive friction between valve stem and packing, lubricate packing with a few drops of graphite bearing oil; use GG grease on packing which requires lubrication. Stop leakage by tightening stuffing-box nuts, forcing packing gland tightly against packing.

b. *Replace Packing.* Gate valves can be repacked without removing them from service. Before repacking, open valve wide. This prevents excessive leakage when packing or entire stuffing box is removed by drawing stem collar tightly against bonnet on a nonrising stem valve, and tightly against bonnet bushing on a rising-stem valve.

(1) *Clean Stuffing Box.* Remove all old packing from inside of stuffing box with a packing hook or a rat tail file with bent end. Clean valve stem of all adhering particles and polish it with fine emery cloth.

(2) *Insert Packing.* Insert new split-ring packing in stuffing box and tamp it into place with packing gland. Stagger ring splits. After stuffing box is filled place a few drops of oil on stem, assemble gland, and tighten it down on packing.

c. *Operate Valve.* Operate inactive gate valves to prevent sticking.

d. *Lubricate Gearing.* Lubricate gate valves as recommended by manufacturer. Lubricate thoroughly any gearing in large gate valves. Wash open gears with kerosene and lubricate with WB

grease or 5190 oil.

e. *Lubricate Rising-Stem Threads.* Clean threads on rising-stem gate valves and lubricate with WB grease.

f. *Reface Leaky Gate Valve Seats.* If gate valve seats leak, reface them immediately, using the method discussed below and illustrated in Figure 3. A solid wedge disk valve is used for illustration, but the general method also applies to other types of repairable gate valves. Proceed as follows:

(1) Remove bonnet and clean and examine disk and body thoroughly (Figure 3-1). Carefully determine extent of damage to body rings and disk. If corrosion has caused excessive pitting or eating away of metal, as in guide ribs in body, repair may be impractical.

(2) Check and service all parts of valve completely. Remove stem from bonnet and examine for scoring and pitting where packing makes contact. Polish lightly with fine emery cloth to put stem in good condition (Figure 3-2). Use soft jaws if stem is put in vise.

(3) Remove all old packing and clean out stuffing box (Figure 3-3); clean all dirt, scale, and corrosion from inside of valve bonnet and other parts.

(4) Do not salvage an old gasket. Remove it completely (Figure 3-4) and replace with one of proper quality and size.

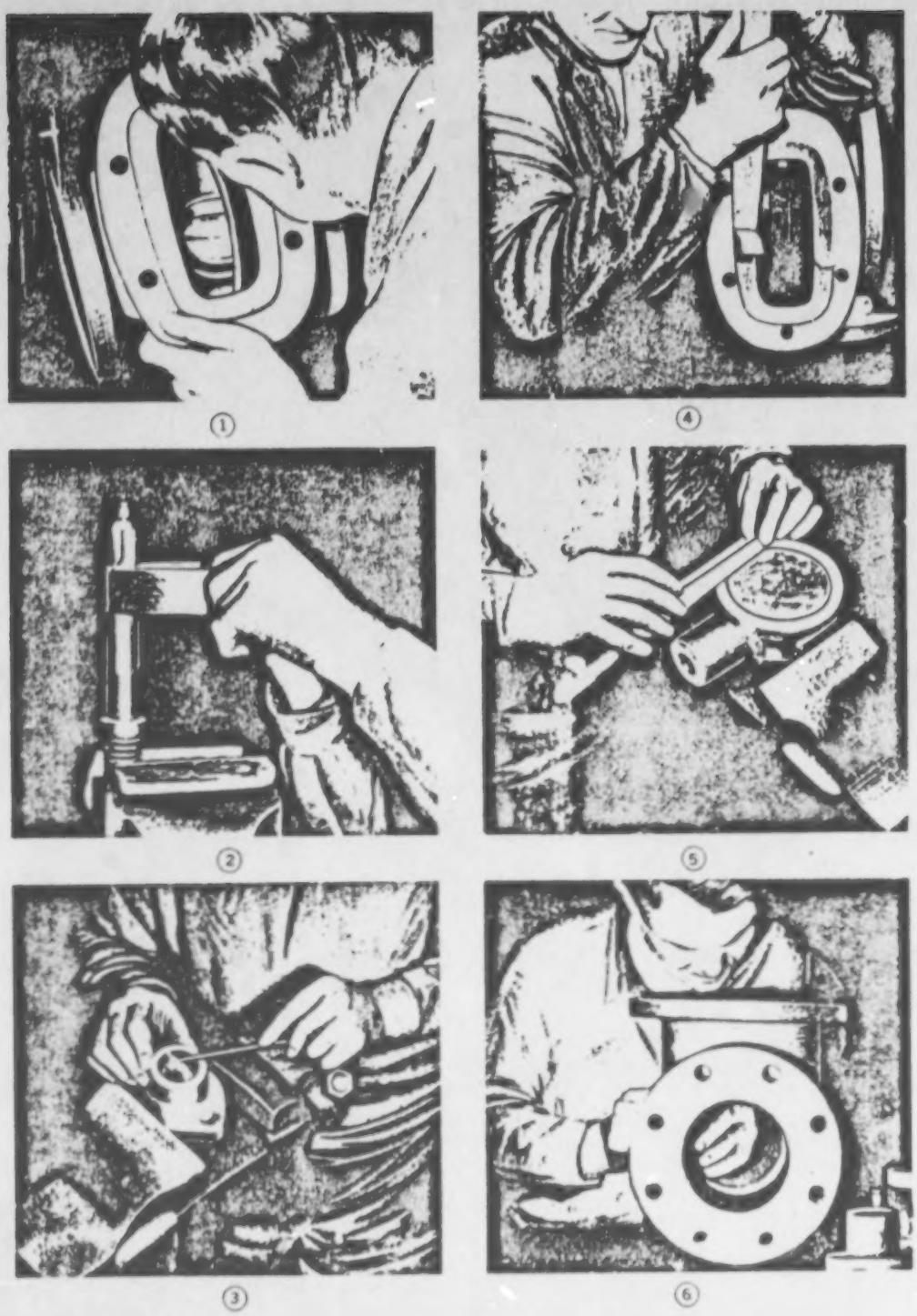
(5) After cleaning and examining all parts, determine whether valve can be repaired by removing cuts from disk and body-seat faces or by replacement of body seats. If repair can be made, set disk in vise with face leveled, wrap fine emery cloth around a flat tool, and rub or lap off entire bearing surfaces on both sides to a smooth, even finish (Figure 3-5). Remove as little metal as possible.

(6) Repair cuts and scratches on body rings by lapping (Figure 3-6). Use emery block small enough to permit rubbing all around rings. Work carefully to avoid removing so much metal that disk will seat too low. After seating surfaces of disk and body rings are properly lapped in, coat faces of disk with Prussian blue and drop disk in body to check contact. When good, continuous contact is obtained, valve is tight and ready for assembly. When assembling, insert stem in bonnet, install new packing, assemble other parts, attach disk to stem, and place assembly in body. Raise disk to prevent contact with seats so bonnet can be properly seated on the body before tightening the joint.

(7) Test repaired valve before putting it back in line to insure that repairs have been properly made.

Figure 3

Steps in Refacing Gate Valve Seats.



(8) If leaky gate valve seats cannot be refaced, remove and replace seat rings with a power lathe. Chuck up body with rings vertical to arbor and use a strong steel bar across ring lugs to unscrew them. They can be removed by hand with a diamond point-chisel if care is taken to avoid harming threads. Drive new rings home tightly. Use a wrench on a steel bar across lugs when putting ring in by hand. Always coat threads with a good lubricant before putting them in. Lap in rings to fit disks perfectly.

Merco-Nordstrom Plug Valves

a. *Adjust Gland.* The adjustable gland holds plug against its seat in body, and acts through compressible packing which functions as a thrust cushion. Keep gland tight enough at all times to hold plug in contact with its seat. If this is not done, lubricant system cannot function properly and solid particles may enter between the body and plug and cause damage.

b. *Lubricate All Valves.* Apply lubricant by removing lubricant screw and inserting stick of LV plug valve lubricant for usual temperature conditions. Check valve fitting within shank to prevent line pressure from blowing out when lubricant screw is removed. Inject lubricant into valve by turning screw down as needed to keep valve in proper operating condition. If lubrication has been neglected, several sticks of lubricant may be necessary before system is refilled to operating condition. Be sure to lubricate valves which are not used often to insure that they are always in operating condition. Leave lubricant chamber nearly full so extra supply is available by turning down on the screw. Use lubricant regularly to increase valve efficiency and service, promote easy operation, reduce wear and corrosion, and seal valve against internal leakage.

c. *Lubricate ACF Plug Type Valves.* To protect them against rust, all stock valves are filled with an assembly lubricant which is extremely soft, white, insoluble in water, and soluble in dry-cleaning solvent. Before placing valve in the line, lubricate with stick LV plug valve lubricant, which readily displaces assembly lubricant. This lubricant can also be used in a grease gun with gasoline as a solvent.

Check Valves

a. *Inspect Disk Facing.* Open valve and observe condition of facing on swing check valves equipped with leather or rubber seats on disk. If metal seat ring is scarred, dress it with a fine file and lap with fine emery paper wrapped around a flat tool.

b. *Check Pin Wear.* Check pin wear on balanced disk check valve, since disk must be accurately positioned in the seat to prevent leakage.

Globe Valves

Metal disks are suitable for throttling service, plug type disks being preferable for severe throttling. Composition disks are not suitable and should be replaced as soon as leakage is noticed to avoid cutting valve seats.

a. *Lubricate Packing.* Lubricate packing, replace if necessary.

b. *Operate Valves and Check for Leakage.* Operate globe valves to prevent sticking. Check valve for leakage and adjust packing nut. Replace disks if necessary.

c. *Regrind or Renew Disk and Seat.* To prevent serious damage, repair disk and seat in globe valves when leakage occurs. Repairs on globe and angle valves can frequently be made without removing them from the line. Figure 4 illustrates the general repair procedure, using a plug type disk valve as an example; however, the method applies to other globe and angle valves, except those with composition disk.

(1) Set valve firmly in vise, straight up (Figure 4-1). Use soft jaws to prevent damage to body. Use a monkey or open end wrench on bonnet or union ring. Do not use pipe wrench, as it will damage these parts. While parts are disassembled, inspect and clean them thoroughly. Renew packing in stuffing box, following method given for gate valves.

(2) Remove stem from bonnet. Place disk in vise and unscrew disk stem ring (Figure 4-2).

(3) Lift out stem and insert slug or coin inside disk to take up play between disk and stem (Figure 4-3). Replace stem and tighten disk stem ring. In some valves a pin is inserted in hole to lock disk on stem.

(4) Apply a *small amount* of emery base grinding compound to both disk and seat (Figure 4-4). Excessive amount of compound removes too much metal.

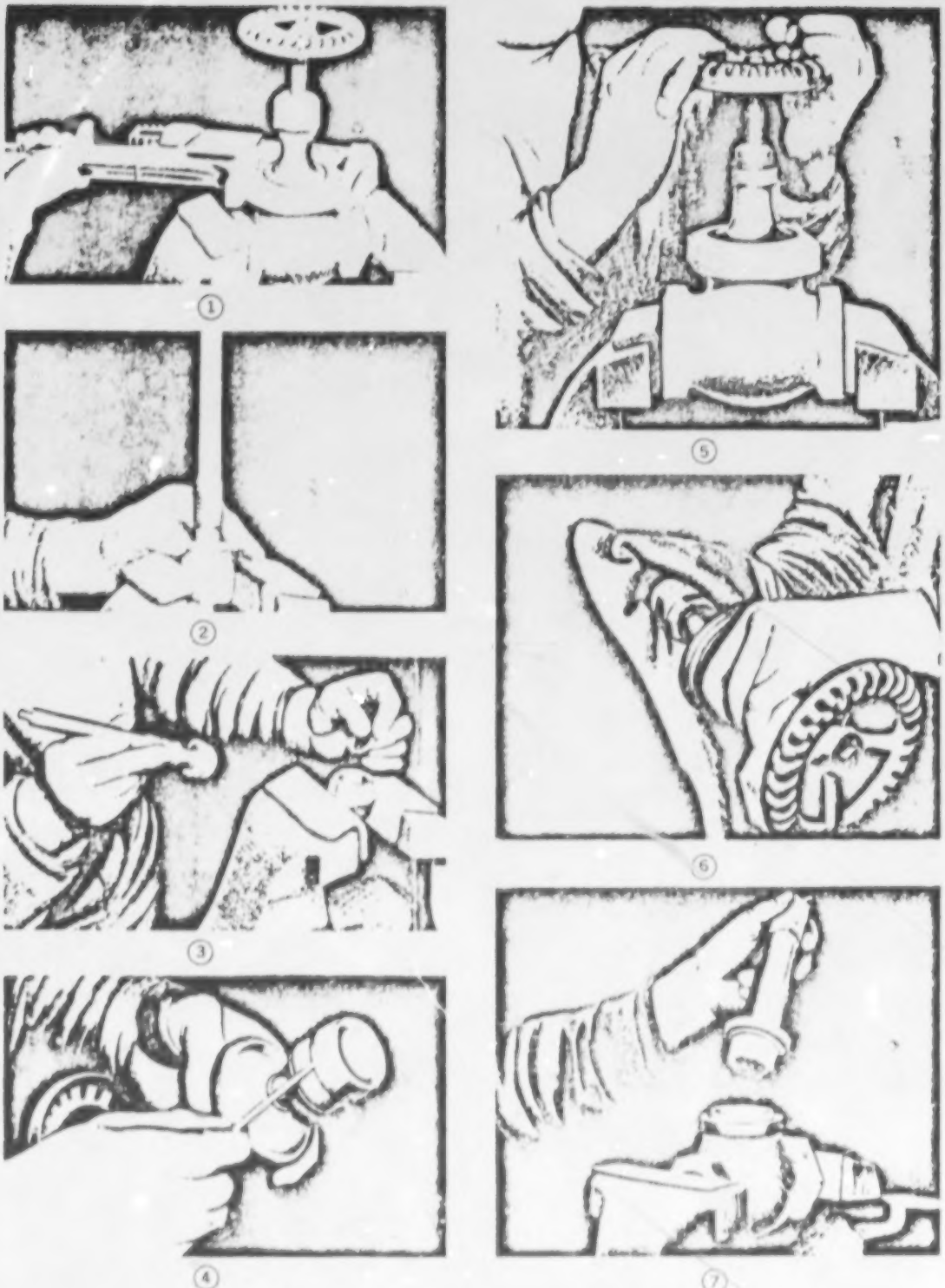
(5) Place bonnet and body together, giving bonnet or bonnet ring two or three turns by hand to provide a guide for stem (Figure 4-5). Keeping a firm hold, oscillate handwheel steadily until all pitting is removed and a continuous, smooth bearing on seating surfaces is obtained. Do not grind more than necessary.

(6) When grinding is completed, wipe disk, seat, and body clean of all compound and dirt (Figure 4-6). Before reassembling valve, remove slug from disk to give it free swivel action on stem.

(7) When seat rings must be removed, use the specially designed tool (Figure 4-7) to prevent damage to valve body.

Figure 4

Steps in Repairing Globe Valves.



Sluice Gates

There are two general types of sluice gates: those which seat with the pressure and those which seat against the pressure. Both are maintained similarly.

a. *Test for Proper Operation.* Operate inactive sluice gates. Oil or grease stem screws with WB grease.

b. *Clean and Paint.* Drain basin. Clean sluice gate with wire brush and paint with proper corrosion-resistant paint.

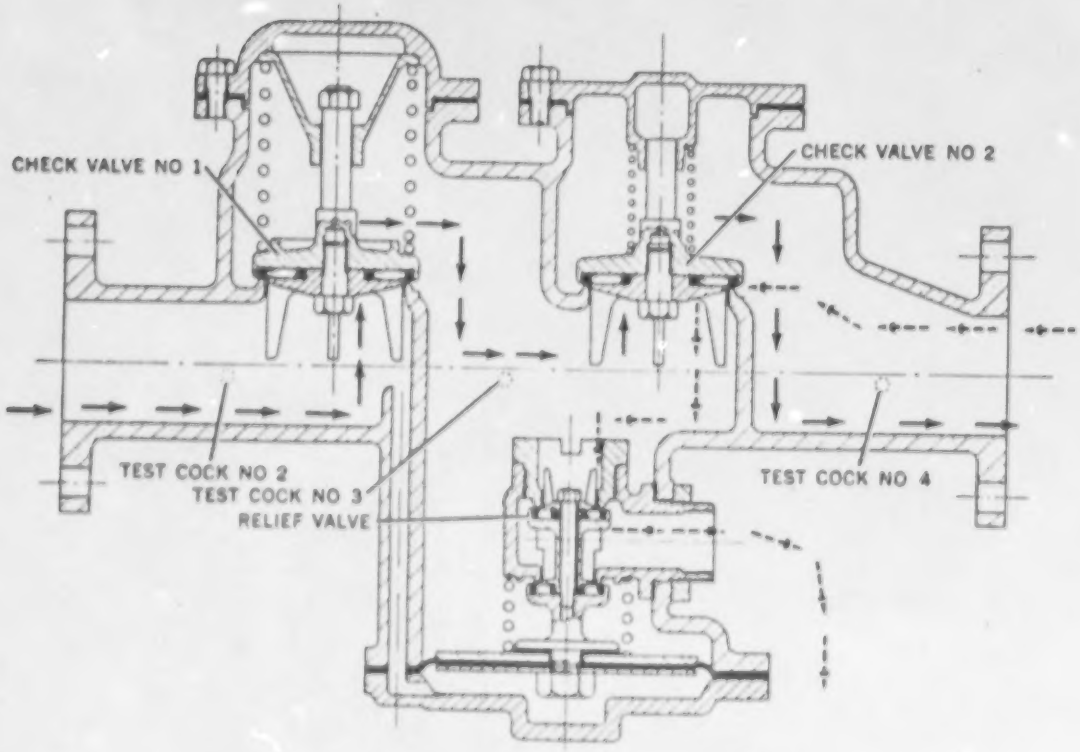
c. *Adjust for Proper Clearance.* For valves seating against pressure, check and adjust adjustable top, bottom, and side wedges until in closed position each wedge applies nearly uniform pressure against gate.

Backflow Preventers

a. *Test Crane Model A Backflow Preventer* (Figure 5):

Figure 5

Crane Backflow Preventer.


CHECK VALVE NO 1
CHECK VALVE NO 2
TEST COCK NO 2
TEST COCK NO 3
RELIEF VALVE
TEST COCK NO 4
TEST COCK NO 1 IS INSTALLED ON INLET GATE VALVE

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(1) *Test No. 1.* To test operation of differential relief valve. (The relief valve must operate to maintain the zone between the check valves at least 2 psi below the supply pressure.)

(a) Install gauges and by-pass fittings at test Cocks #2 and #3.

(b) Close No. 2 gate valve.

(c) Install by-pass hose from test cock #2 through a control valve to test cock #3.

(d) Open test cocks #2 and #3.

(e) Open control valve on by-pass slowly and note readings on pressure gauges when relief valve opens and starts to drain water. The pressure reading at test cock #3 must be at least 2 psi below the pressure at test cock #2; otherwise the relief valve is not working properly.

(2) *Test No. 2.* To test No. 1 check valve for tightness.

If the relief valve is operating on reduced pressure and there is no drainage from it when gate No. 2 is closed, the No. 1 check valve is not leaking, and is working properly.

(3) *Test No. 3.* To test tightness of check Valve No. 2.

(a) Gate valve No. 2 still closed.

(b) Install the by-pass hose from test cock #2 to the test cock #4.

(c) Open test cock #2 and #4. If water is discharged from the relief valve, No. 2 check is leaking. If no water is discharged from the relief valve, No. 2 check is tight.

Note: Leaky gate valves and leaky or faulty test equipment will give erroneous test results; it will be necessary, therefore, to investigate both gate valves for leakage and to repair or replace them if found defective. Test equipment should have no leaks, however slight.

(4) *The Backflow Preventer is working properly if all of the following conditions are true:*

(a) *Test A*--There is no discharge from the relief valve opening when water is flowing through the device in normal direction. No discharge under this test indicates that there is no foreign material under relief valve seats.

(b) *Test B*--There is no continual discharge from the relief valve opening when gate valve #2 only is closed. (Intermittent discharge may occur if there are pulsations in the supply pressure, but this is normal operation.) This test indicates that

the first check is tight.

(c) *Test C*--The relief valve opens to discharge water and maintains the pressure at test cock #3 at least 2 psi below the pressure at test cock #2 when pressure is brought through a hose from test cock #2 into test cock #3.

(d) *Test D*--With gate valve #2 closed, there is no discharge from the relief valve when pressure is brought from test cock #2 through a hose into test cock #4. Drainage from the relief valve under this test would indicate that the 2nd check is leaking.

(5) *The Backflow Preventer is not working properly if any of the following conditions are true:*

(a) There is continual discharge from the relief valve when water is flowing through the device in normal direction. Discharge under this condition indicates foreign material under the relief valve seats.

(b) There is continual discharge from the relief valve when gate valve #2 is closed. Discharge under this condition indicates foreign material under the seat of the first check valve.

(c) There is no discharge from the relief valve when pressure is brought from test cock #2 through a hose into test cock #3. Under this condition the relief valve *should* open and discharge water, and maintain the pressure at test cock #3 2 psi below the pressure at test cock #2.

(d) There is discharge from the relief valve when pressure is brought from test cock #2 through a hose into test cock #4. Drainage from the relief valve under this test indicates that the 2nd check is leaking.

(6) *To Repair Crane--Line Backflow Preventer:*

(a) The relief valve must be disassembled as follows:

1. Remove lower cover plate.
2. Remove outside lock nut.
3. Entire relief valve assembly can then be removed and cleaned or repaired.

(b) Foreign material under seat of first check valve. Remove cover plate over first check (or pipe plug on smaller sizes); lift out check valve and clean or repair.

(c) Failure of relief valve to open and discharge, thereby maintaining zone of reduced pressure, or failure to maintain the pressure at test cock #3 at least 2 lb. below pressure at test cock #2. (This rarely, if ever, occurs.)

1. Disassemble and clean as under II-A, and replace spring if necessary.

(d) Foreign material under 2nd check valve. Remove cover plate over second check (or pipe plug on smaller sizes); lift out check valve and clean or repair.

Note: It is recommended that a strainer be installed on the upstream side of the backflow preventer.

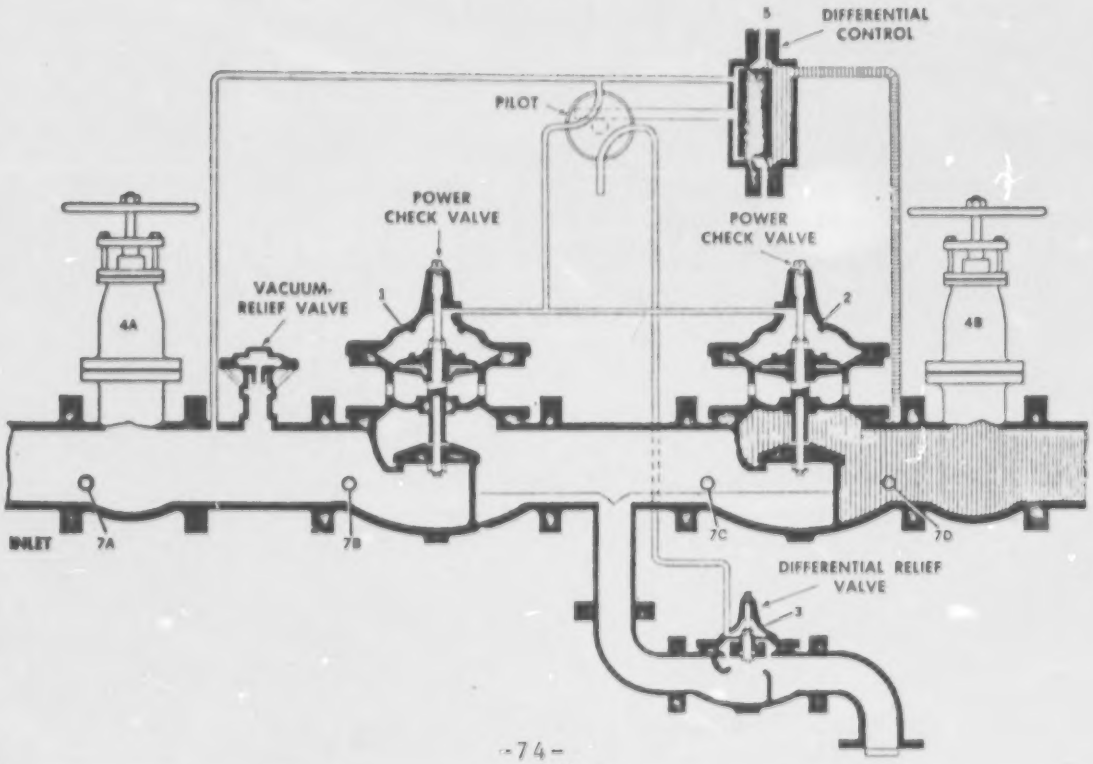
b. *Test Clayton No. 3 Backflow Preventer.* Operation of the No. 3 backflow preventer is fully automatic. There are no adjustments necessary. After it has been properly installed the only attention required is a periodic testing program to insure the proper functioning of the unit and to obtain advance notice of the need of repair. This test must be performed at least every six months, or more frequently for the more important installations. (See Figure 6.)

(1) *Test Procedure Equipment Required:*

(a) Length of 3/4-inch hose long enough to reach from test cock (7A) to test cock (7D). For convenience equip the hose with swivel connectors having pipe thread ends sized to match the test cock tapping.

Figure 6

Clayton Backflow Preventer.



(b) A plug or blind flange to blank off the outlet from the differential valve (3).

(2) *Test Check Valves:*

(a) Connect hose from test cock (7A) to (7D). If the inlet gate valve does not have a test cock corresponding to (7A) one should be installed as close to and upstream from the inlet gate valve.

(b) Close both gate valves at the inlet ends of the unit. *These valves must hold tight.*

(c) Open test cocks (7A), (7C), and (7D). Discharge of water from cock (7C) is an indication that the downstream check valve (2) is leaking.

(d) Close test cocks (7A), (7C), and (7D).

(e) Blank off the discharge from differential valve (3) by installing pipe plug or blind flange on the outlet.

(f) Disconnect hose from test cock (7D) and connect it to test cock (7C).

(g) Open test cocks S(7A), (7B), and (7C). Discharge of water from test cock (7B) is an indication that the upstream check valve (1) is leaking.

Note: The importance of a tight-sealing inlet gate valve can be seen at this point. If the gate valve leaks, the flow from test cock (7B) might lead one to believe erroneously that the inlet check valve (1) is leaking.

(h) Close test cock (7B) and (7C).

(i) Remove plug or flange from the outlet of differential valve.

(3) *Test Differential Valve:*

(a) Open test cock (7C), and then open (7B) slowly. Watch the indicator stem on differential control (5). As pressure is bled from above the diaphragm of differential control (5) to atmosphere through test cock (7B) the indicator stem should rise. This indicates that the control has shifted to open valve (3). Flow should then be observed from the differential valve (3) outlet.

(b) Close test cock (7B) and open inlet gate valve slightly. Differential control (5) should shift (indicator stem goes down), and valve (3) should close.

(c) Close all test cocks, remove hose, and open both inlet and outlet gate valves.

METERS*

Meters provide the only fair and equitable method of distributing the cost of water supply. They are one of the most economical means of combating waste and usually pay for themselves through reduced plant requirements or postponement of plant additions. Meters are the cash register of the water system and, accordingly, should be maintained in proper working order.

Continuing research has resulted in improvement in the design of meters. The magnetic drive design overcomes the difficulty of fogged glasses, which render meter reading so difficult. Research work has also resulted in plastics being used for the working parts of the meter rather than metallic components that, in some types of water, become badly corroded and pitted.

Purposes of Maintenance

The benefits of a scheduled meter maintenance program are increased revenue; a uniform, stabilized work load; and the advantage of being able to perform preventive maintenance and avoid a continual succession of emergencies. Large losses of revenue result from the practice of removing a meter only when a service is discontinued or when the meter has stopped registering. The cost of meter removal and repair is minor when compared with revenue lost by low registration or no registration.

It should be constantly borne in mind that, although a metered system is the best basis known for equitably spreading the cost of water service, serious inequities and injustices can be introduced unless the meters can be maintained at a high, uniform level of efficiency.

Frequency of Meter Tests

Periods between tests are influenced by such factors as the rates charged for water; the effects of waters of different chemical characteristics; and the cost of removing, testing, repairing, and reinstalling the meters. State regulatory commissions have adopted maximum periods between tests for most privately owned water utilities and for some publicly owned systems. These periods generally are expressed in maximum number of years between tests for various sizes of meters, sometimes with an overriding period, based upon a maximum quantity of water passing through the meter. The maximum period for 5/8-in. meters ranges between 3 and 10 years with 5- and 10-year periods being most common. For meters of sizes 3/4 in. through 3 in., the period ranges from 2 to 8 years, and 4 in. or larger, it ranges from 1 to 4 years.

*Source: Waterworks Manual - basic, P71-54, Coordinating Council for Occupational Education, State of Washington, 1972, pp. 192-196.

It should be noted that any arbitrary time interval applied to different localities, each with its own local conditions, cannot be economically correct for all. It is not logical, but true, that meter maintenance, in too many instances is considered to be of little importance, as something done only when other types of work that cannot be as readily deferred are out of the way. It is recommended that small water systems that do not have a testing program set one up on the basis of testing once every 10 years for the smaller meters and more frequently for the larger ones. As actual test results of meters removed from service are accumulated, experience is obtained as to the length of time it takes, on the average, for meters to lose sensitivity on low flows, and the length of time meters are permitted to remain in service can be adjusted on the basis of known results. There is no substitute for experience in arriving at the best answer.

The equipment required to test a water meter may be very simple. The test procedure may consist simply of timing the flow through a meter set in the line discharging into a tank on a set of scales to weigh the water. An orifice may sometimes be used. Where the number of meters to be tested warrants, more elaborate test equipment is commercially available. Water meter test requirements have been published in AWWA standard C 705.

Basic Maintenance and Repair

The maintenance and repair of positive-displacement meters consists essentially of dismantling, thoroughly cleaning, and inspecting all parts. After dismantling, the measuring chamber should be carefully inspected for pitting, and the moving parts and appurtenances, such as the disc, thrust rollers, and slots, checked for excessive wear and corrosion. The disc should be checked with a straightedge and examined for swelling and distortion caused by freezing, heat, or hot water.

After defective and badly worn parts have been replaced, the disc should be reassembled in the chamber. Proper clearances should be provided and shims should be inserted if required. The gear train should run freely and mesh smoothly, and spindles should be checked for wear and bushed if required. Gear teeth should be examined for wear.

Some of the important points to remember in meter maintenance are:

.....Clean all meter parts thoroughly.

.....Make sure the gear train runs freely.

.....Check the action of the disc in the chamber before and after assembly in the main casing.

.....Remember that friction is just as detrimental to correct registration as slippage.

.....Store meters away from heat.

.....Use a new meter as a standard of comparison for tolerances and clearances.

.....Retest the meter for accuracy after repair.

.....If necessary, call upon the manufacturer for advice and help.

The maintenance and repair of other types of meters follow essentially the same procedures, the differences largely resulting from the variations in construction. Efficiency is promoted by determining the best means of travel of the meter through the repair shop in carrying out the various elements of testing, maintenance, and repair.

Cleaning

Every meter coming into the shop for repairs should be dismantled, and all parts should be thoroughly cleaned. If there is no time to clean a meter immediately, one end of the spud should be capped, and water should be run into it under a faucet. When the meter is full of water, the top or open end of the other spud should be capped, and the meter should be allowed to stand in an inverted or upright position until it can be dismantled. This method keeps the deposits from the water soft and makes dismantling and cleaning easier. Because designs for types of meters vary widely, uniform procedures are impossible and therefore are not given in this appendix.

Numerous methods and chemicals are used for cleaning water meters. Hot alkaline solutions are used to wash off oil and grease films, and cold acid solutions remove lime deposits, rust, and corrosion. Rubber in meters is not normally affected by either acid or alkaline solutions, but the temperature at which alkaline solutions are usually employed (approximately 160° F) would ruin hard-rubber parts. Regardless of which type of solution is used, meter parts should be rinsed in clean, cold water before reassembly to avoid corrosion from acids remaining in the crevices. Overdipping in strong acids should be avoided.

If abrasive cleaning materials are used, the abrasive action may continue for quite some time after assembly unless the chamber is thoroughly cleaned and rinsed. A wire brush may be used to remove scaling and deposits, but should not be employed too vigorously. Measuring chambers should not be sandblasted as sandblasting destroys the machined surfaces on the inside.

More detailed instructions on the testing and maintenance of water meters are contained in AWWA Meter Manual M6.

Change Gears

Gear trains of the open or enclosed types should be completely disassembled. The wheels, pinions, and spindles should be checked for wear and replaced if necessary. The hard-rubber bushings in the top and bottom plates should be checked for wear. If excessively worn, they should be replaced. The holes in the bushings can be checked for wear by using the spindle in a new wheel as a guide. The holes can also be checked with the shank of a drill of the same diameter as a new wheel spindle. The method of removing hard-rubber bushings depends upon the number of gear train plates to be rebushed. A pair of change gears is located directly under the register, one on the register driving spindle and one on the stuffing box spindle. To change calibration, these gears are removed and replaced by a pair having a different ratio.

It is recommended that manufacturers be consulted regarding detailed instructions for carrying out this and other repair work.

Meter Records

A suitable record of meters is one that provides full and complete information on the installation, repair, and testing of each meter with a minimum of expense. The time devoted to maintaining complete records is considerable because of the number of units involved and the probability that they will not remain at one location during their life. Any system of meter records should provide such basic data for each meter as size, make, type, date purchased, where the meter is located at all times, and data on all tests and repairs. One method for maintaining such records is by use of a meter history card. The upper line of the test and repair record section is used to record the test results for the meter upon its removal from service and the lower half to record the final test results before the meter is reinstalled.

This method of maintaining meter records is a good one but requires repeating much detailed information from other primary records. The work involved might be compared with a system that uses the following forms:

.....Service order
.....Service envelope
.....Meter envelope
.....Report on meter tests and repairs

Briefly, the service order authorizes work to be done. The service envelope contains records concerning the particular service location served. Its service number is never changed. The meter envelope is prepared for each meter on the date of purchase, and the dates of installation and removal are posted to this envelope from service orders. Dates of tests of the meter are posted to this envelope from the report of meter tests and repair. Reports of meter tests and repairs are made out from service orders for each meter removed from service. Actual repair data obtained from the reports are filed inside the meter envelope.

DISINFECTING MAINS AND STORAGE TANKS*

GENERAL

Before we delve into the subject, we need to establish some common terminology.

The words disinfection, sterilization, and chlorination are used interchangeably by water utility personnel. For this article, disinfection is the word of choice.

Disinfection means the destruction of, or the rendering harmless of, disease-producing bacteria. Sterilization is the complete destruction of all organisms and is desired in the bacteriological laboratory preparation of utensils. Chlorination means disinfection by the use of the chemical chlorine.

There is more than one method available to achieve disinfection. Chlorination will be the only method mentioned in this article. Therefore, a word about chlorine. Chlorine is a strong oxidizing agent and is toxic. It is available in three forms, any of which may be used to disinfect "water utensils:"

1. Gas-99.99 per cent pure, soluble in water, and, therefore, easily adaptable to solution feeding.

2. Calcium hypochlorite-dry form, 65 per cent to 70 per cent available chlorine, and comes in powder, granular, or tablet form. It is relatively soluble in water, and, therefore, adaptable to solution feeding.

3. Sodium hypochlorite-liquid form. It is 5 per cent to 16 per cent available chlorine. It comes in sizes from one-quart containers to five-gallon carboys.

Every water utility personnel should be familiar with chlorine safety and with the physical forms of chlorine. The previous information was inserted as a reminder of the properties and dangers of chlorine.

*Adapted from the article "Disinfecting Mains and Storage Tanks" by Robert L. Stevens and Jack C. Dice, Denver Water Department, from OPFLOW, a monthly publication for members of the AWWA, September and October, 1977.

CREW TRAINING

One of the most important factors in ensuring proper disinfection of water lines is well trained installation crews. They must be acutely aware of the reasons for and the proper approach to disinfection in order to avoid unnecessary contamination of the water line. Extraneous material-organic, inorganic, dirt, or debris-reduces the effectiveness of the chlorine and may require excess flushing or even re-disinfection of the entire job. The interior of each section of line should be inspected for debris as the line is laid in the trench. If necessary, a swab of soft material should be pulled or pushed through the section of line. Large lines, 24-in. ID or larger, can be physically inspected for items that may have been left behind. The trench should be dewatered of all seepage water and water-tight plugs should be installed in openend joints whenever the trench is unattended for any length of time. Welding rods, rags, gloves, small hand tools, rocks, cardboard boxes, cats, rabbits, and skunks are just a few of the items that have been known to be removed from water lines, some of them after the line has been operating for some time.

Obviously, it is easier to maintain clean conditions while installing new lines in dry trenches-disinfection procedures not being as reliable while repairing a line in a flooded trench, especially while the crews are under pressure to close and re-establish service. Well trained crews and an informed foreman are essential in this program.

METHOD OF APPLICATION

Chlorine gas may be used. However, many precautions need to be taken, and very frankly,we do not recommend this as the method of choice, especially for untrained personnel. Gas should be applied only with the proper equipment and under the direct supervision of a person thoroughly trained and familiar with every aspect of its application. Preferred equipment consists of a solution-feed chlorinator in combination with a booster pump. Applying gas directly from the cylinder is dangerous and direct-feed chlorinators are not recommended.

CONTINUOUS FLOW

A universal method of chlorine application is the so-called continuous flow method. It is best suited for large-diameter pipelines (12 in. or greater), but may be used for any size of line.

Assume that 10,500 ft of 12-in. cast-iron line is to be disinfected by the continuous flow method. What are the steps in the operation? First, assume that 70 per cent calcium hypochlorite, granular form, will be the source of chlorine. Disinfection will be accomplished by applying 50 mg/l of chlorine during a 24-hr contact time.

Next, the volume of water to be treated and the amount of chlorine to be used must be calculated. When calculating volume: $V = \pi r^2 \times L \times 7.48$; therefore, $V = 3.14 \times (0.50)^2 \times 10\,500 \times 7.48 = 61{,}635$ gallons. When calculating pounds of chlorine: pounds of Cl_2 = million gallons x $\frac{8.34}{\text{per cent of } Cl_2}$ x mg/l desired; therefore, pounds of Cl_2 = $0.062 \times \frac{8.34}{0.70} \times 50 = 37$ lb of 70 per cent Cl_2. Therefore, 37 lb of 70 per cent chlorine must be fed to 0.062 million gallons of water to achieve a chlorine concentration of 50 mg/l.

The next step is a preliminary flushing. Flushing is a minor item that becomes a major item if not considered in the planning stage. Drainage must be adequate and no property damage must occur. What about the NPDES* program in your area if the water reaches the stream? Preliminary flushing should be accomplished at a rate of 2.5 feet per second in order to purge the line of dirt and debris. Flushing is no substitute for preventive measures while laying pipe.

In the continuous flow method, water from an approved source is channeled to flow into the new line at a constant measured rate. The chlorine is also applied at a constant measured rate. The two rates are proportioned so that the chlorine concentration is uniform and at the desired 50 mg/l. In this assumed disinfection project, the chlorine is added as a 1 per cent slurry from 50-gal barrels to the pipeline with the use of an aspirator. By calculation, 6 lb of 70 per cent chlorine in 50 gallons of water equals 10,000 mg/l, or a 1 per cent solution. Thirty-seven pounds of chlorine are needed for the project. Therefore, six barrels of 50 gal each will be proportioned into the new line. Water from the distribution system is allowed to flow into the new line and both flows are adjusted so that one 50-gal barrel is applied to approximately 10,000 gal of incoming water. Chlorine residuals are then taken to ensure the 50-mg/l concentration. The valve is then closed and the chlorinated water remains in contact with

* National Pollutant Discharge Elimination System

the line for 24 hr. The line is then flushed to waste until the chlorine residuals are approximately back to normal. Then, bacteriological samples are collected and must be negative for coliform organisms before the line can be released for service.

Previously we discussed some general principles of disinfection such as crew training, using (or not using) gaseous chlorine, and the continuous flow method of disinfection. We will now cover the use of chlorine tablets and clear-water storage disinfection. The basic references for these subjects are (1) AWWA standard C601-68, "Disinfecting Water Mains," and (2) Section 5 of AWWA standard D102-64, "Painting and Repainting Steel Tanks, Standpipes, Reservoirs, and Elevated Tanks for Water Starage." These standards should be a part of every utility's library.

TABLETIZING

The method of disinfection that is best suited for small utilities and small diameter lines (12 in. and less) is that of using high test hypochlorite in the form of tablets. The tablets are calcium hypochlorite and contain between 65 and 70 per cent available chlorine.

For the sake of simplicity, let us imagine a disinfection project and use tablets as the chlorine form.

The plans call for 846 ft of 8-in. diameter cast iron pipe in 18-ft lengths. We will disinfect at a concentration of 50 mg/l with a 24-hr contact time. The first step is to determine the number of tablets that will be needed. This chore is accomplished for you if you have a copy of AWWA standard C601-68. Table 3 on page 5 of the standard is a schedule of the number of tablets per section of pipe by length and diameter. Table 1 of this article is a reproduction of that table.

TABLE 1

Number of Hypochlorite Tablets of 5g Strength Required for a Dose of 50 mg/l*

Length of Section ft	Diameter of Pipe in.					
	2	4	6	8	10	12
13 or less	1	1	2	2	3	5
18	1	1	2	3	5	6
20	1	1	2	3	5	7
30	1	2	3	5	7	10
40	1	2	4	6	9	14

*Based on 3 3/4g available chlorine per tablet.

The table indicates to use three tablets per section of 18-ft length 8-in. diameter pipe. If 18 ft equals one section of pipe, then 846 ft would require 47 sections of pipe (846 ÷ 18). If three tablets are required per section, then 141 tablets are required for the total job (47 x 3).

If you do not happen to have a chart handy, you can determine the amount of chlorine needed by the formula discussed earlier. Using those calculations, 846 ft of 8-in. diameter line will hold 2154 gal of water. It will require 1.2 lb of 70 per cent hypochlorite to disinfect at a concentration of 50 mg/l. The label on a container of tablets states that approximately 7 tablets equals 1 oz. Therefore, 112 tablets equals 1 lb (7 x 16), 1.2 lb x 112 tablets equals 134 tablets needed for this project. Forty-seven sections of pipe are required. 134 tablets ÷ 47 sections = 2.85 or 3 tablets per length of pipe. The approximate weight of the tablets to be used and the percentage of chlorine available should be noted from the container label so that the proper figures can be used in the calculations or table notes.

Since a preliminary flushing cannot be achieved when using the tablet method, the pipe-laying crew must take every precaution to see that the pipe interiors are clean and free from debris, and that the trench is dry and free from seepage water.

Place three tablets in each section of line as it is placed in the trench. It is not advisable to place tablets too far in advance of laying. Moisture in the atmosphere reduces the percentage of available chlorine. Also, children in the area could remove the tablets after working hours and cause damage to themselves or others.

The tablets should be adhered to the upper quadrant of the pipe with an adhesive, such as Permatex No. 1. Place the adhesive on the broad side of the tablet and take care not to use excess amounts. A mark should be placed on the outside of the pipe so that the pipe-laying crew will know to keep the tablets on the upper side and not rotate the pipe.

After the 47 sections have been laid, valves must be manipulated so that the line is filled at a velocity of 1 fps. or less, making sure that the line is purged of air. The line is then left for 24 hr to allow the tablets to dissolve and the disinfection process to take effect. The procedure from this point is the same as for the continuous flow method; that is, residual testing, bacteriological testing and flushing before the line can be released for use.

Two more points must be made on the use of chlorine tablets. (1) Adequate disinfection is based on a time-concentration ratio. The tablets will not dissolve readily if

the water temperature is below 41F (5C), which reduces the concentration. You may not have control over the water temperature, but you can control the contact time. So, if you are disinfecting when the water temperature is low, allow more than 24 hr for the contact time. (2) Tablets may be crushed and placed in joints in hydrant branches to assist in the total disinfection process.

EMERGENCY OR MAINTENANCE DISINFECTION

A method not found in the standards but used successfully by several utilities is that of spraying chlorine for disinfection of pipelines. This method is best used for disinfecting sections of pipe at a main break repair or where the crew has to cut into an existing system, or in very short line extensions (less than 100ft). This method can be utilized when circumstances do not allow for a 24-hr contact time. It can be used as a substitute for the swab method described in Section 11 of AWWA standard C601-68.

A chlorine solution of between 1 and 5 per cent concentration is pressurized at approximately 100 psi in an ordinary pressure type stainless steel fire extinguisher. The solution is applied to the complete interior of a section of pipe or fitting as it is lowered into the trench. Pipe sections or fittings sprayed prior to installation must be sealed at the ends with plastic sheeting. Bacteriological analyses must be performed after the line has been charged. The stainless steel extinguisher will not corrode as rapidly from the contact with the chlorine solution if the interior of the tank is lined with a protective coating, such as a chlorinated rubber or an epoxy type coating. The spray method of disinfection has proven to be successful but it must be used with discretion under proper and controlled circumstances.

STORAGE FACILITIES

In order to maintain quality and to prevent the occurrence of taste-and-odor problems, clear-water storage facilities should be drained, cleaned, and disinfected on a routine basis. One method to accomplish this feat is as follows: Once the basin has been emptied, the cleaning crew can move in and wash down the walls, stanchions, and floors with high pressure fire hoses or long-handled scrub brushes. When the basin has been rinsed free of accumulated debris, then the walls, stanchions, and floors must be disinfected. This can be accomplished by spraying

the facility with a 200-mg/l chlorine solution. The chlorine solution can be provided from a tanker filled with the proper concentration of disinfectant. The application can be accomplished by using garden hoses with nozzles, and pressure can be provided by a gasoline driven pump. A 200-mg/l concentration is neither dangerous nor uncomfortable to work with inside of a storage tank. However, adequate ventilation should be provided, the amount and type depending on the situation. If there are multiple hatches they should all be opened. If there are too few hatches, blowers and fans should be provided to circulate the air.

CONCLUSION

The water supply industry is supplying a product that is consumed by the general public. This product has and can transmit diseases and illnesses. Therefore, all measures should be taken to provide a safe product. Disinfecting water mains and storage facilities is one measure that should be taken. The AWWA standards C601-68 and D102-64 are only two of many tools available to assist operators in accomplishing this task. If you do not have these standards, you should obtain them from AWWA.

RECOATING STORAGE TANKS AS PART OF TANK MAINTENANCE*

Problems Related to Surface Preparation

One part of the total paint coating project that is often overlooked is what I would term "housekeeping practices." An outstanding sandblasting job can be wasted if proper cleanup procedures are not exercised before the process of application is begun.

Choice of Material and Coating Application

This part of the tank coating project probably provides more opportunities for potential coating failure due to particular procedures or techniques. It is in this area where close control is needed to prevent sources of trouble-not only in new tank coatings but also in maintenance work. Some of these potential problems follow.

Compatibility of coatings is one problem that can occur in maintenance painting programs. This comes into focus when a coating is to be changed from that previously used and removal of the old coating is not yet scheduled. Even though the old coating is sound and adhering well, applying a new different type of coating over the top of an old one may create serious problems. The solvents in the new coating may easily dissolve or have a thinning effect on the old coating and actually "lift" it from the tank. The paint manufacturer should be consulted before this procedure is enacted.

The improper use of solvents or thinners is a common fault. To remedy the solution of an application or spray-pattern problem, thinners are used and this is a genuine source of paint coating failure, particularly when using the more viscous or high-solids coatings. Trapping solvents between coatings because of excessive thinner and inadequate

*Adapted from the article of the same title by K.C. Mueller, V.P. and Assistant Manager, Missouri Water Company, Independence, Missouri; from OpFlow, a monthly publication for members of the AWWA, March and April, 1977.

curing time has been experienced. Blisters have been formed, which when popped, produce the actual solvent fluid which was present in excess. With the availability of airless spray type equipment, the use of solvents or thinners can be more easily controlled.

Adequate drying or curing time of coatings is particularly needed when coating the inside of closed reservoirs, standpipes, or elevated tanks. Curing in these environments can only be done effectively by forced-draft ventilation. Not only is it vital to provide ventilation or movement of air but also sufficiently lengthened time of curing is essential to be certain that the coating has cured completely. Insufficient drying or curing time can also cause taste-and-odor problems in the water when the tank is filled. I recommend that, where possible, you extend the curing time recommended by the paint manufacturer by as much as 100 per cent, depending upon conditions.

Excessive time between a prime coat and a finish coat can be a major factor in the failure of a tank-coating system. This is particularly true when the prime coat is shop applied and the steel tank components are shipped and erected during cold weather. Several months may elapse between the time the primer is applied and the finish painting is accomplished. In many cases the prime coat is not designed to serve as a "weathering" coating. Long periods of time may deteriorate the prime coat and if only the weld areas are cleaned and primed after erection, large areas of the "flat steel" may already be a source of trouble. If the finish coat is applied over primer that has weathered, premature failure of the entire coating can occur easily.

Application Techniques

There are two vitally important application techniques that should be used in all tank painting projects:

1. After surface preparation all welds, edges, and corners should be given a brush or spray coat of the appropriate primer before the balance of the primer is applied. This has proven to be extremely helpful in preventing premature coating failures.

2. As reported in the literature,

> To deposit an adequate film thickness (final coat or primer), it is necessary for the painter to follow a procedure known as cross spraying; that is, to spray a certain area with horizontal strokes overlapping 50 per cent, then to respray the same area with vertical strokes overlapping 50 per cent.[1]

This procedure of cross spraying is extremely important not only to obtain adequate film thickness, but also to reduce greatly the chance of holidays.

Specifications

After interviewing several painting contractors throughout the central and eastern areas of the US, it is my opinion that the use of specifications for tank painting jobs is an absolute requirement. Every utility and contractor interviewed expressed that specifications are necessary. The real test occurs when the inspector appears to see that the conditions of the specifications were met.

Inspection

Inspection is a difficult and vital part of the tank coating project. Based upon personal experience, the task of inspecting the coating on some tanks, particularly elevated tanks, is difficult even for a person who is adaptable to working in high places. Inspection, as discussed in this article, should secure the following:

1. Proper thickness.
2. Uniform coating (free of holidays).
3. Use of proper safety precautions.
4. Proper surface preparation.
5. Proper housekeeping procedures.

1 Christofferson, D.W. Coatings for Steel Water Storage Tanks, Jour. AWWA, 53:6:725 (Jun. 1961).

Maintenance Records

Keeping maintenance records on tank painting and inspections is very important. The use of photographs during tank inspections is an excellent way of recording permanently the results of coating wear and type of coating failures. Keep a chart or table of pertinent data over the years.

Summary

Tank maintenance procedures have become refined over the years and a search of the literature indicates that more efforts have been spent to improve coatings and reduce the cost of maintenance.

One subject that was not discussed in this article is the use of cathodic protection systems. When used with paint coating systems, they can provide an excellent way of extending the life of steel tanks and reservoirs.

Improved tank design, including the use of high-strength or special alloy steel, must be considered as a means of reducing future maintenance costs. Elimination of irregular shapes for roof supports can also reduce maintenance problems.

Progress has been made, and through the efforts of AWWA and organizations such as the Steel Structures Painting Council, the task of tank maintenance will be lessened.